STATE OF CALIFORNIA
DEPARTMENT OF NATURAL RESOURCES

DIVISION OF MINES
FERRY BUILDING, SAN FRANCISCO

WALTER W. BRADLEY State Mineralogist

Vol. 40 JANUARY 1944 No. 1

CALIFORNIA JOURNAL

OF

MINES AND GEOLOGY

QUARTERLY CHAPTER

OF

STATE MINERALOGIST'S REPORT XL

DIVISION OF MINES

EXECUTIVE AND TECHNICAL STAFF

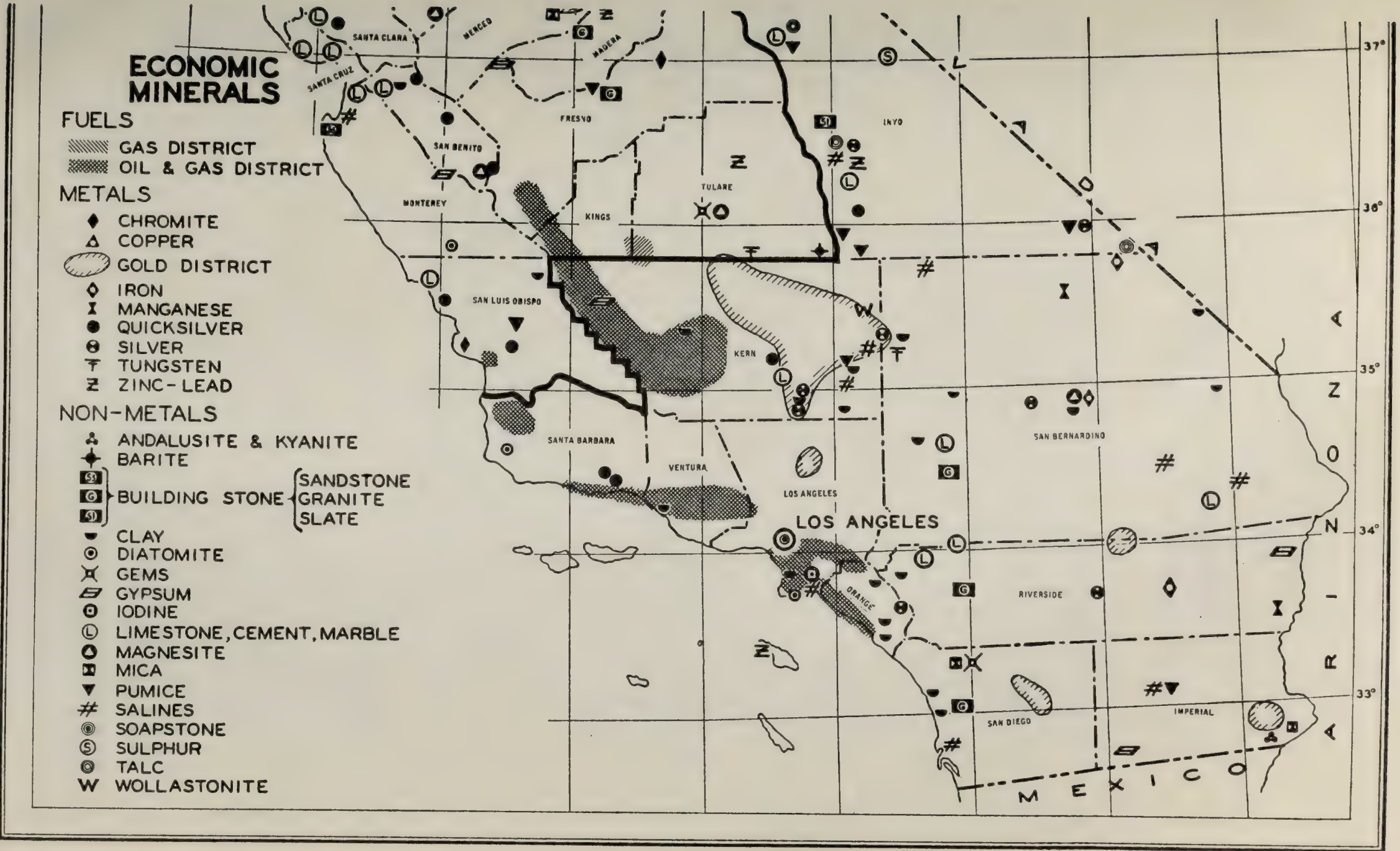
WALTER W. BRADLEY
State Mineralogist

OLAF P. JENKINS, Chief Geologist	San Francisco
C. A. LOGAN, District Mining Engineer	San Francisco
W. BURLING TUCKER, District Mining Engineer	Los Angeles
REID J. SAMPSON, Assistant District Mining Engineer	Los Angeles
CHAS. V. AVERILL, District Mining Engineer	Sacramento
J. C. O'BRIEN, District Mining Engineer	Redding
GEORGE L. GARY, Mineral Technologist	San Francisco
JOHN F. BONGARD, Ore-Buyers' Inspector*	San Francisco
HENRY H. SYMONS, Statistician and Curator	San Francisco
JAMES M. LITTLE, Junior Mining Engineer (Librarian)	San Francisco
ELISABETH L. EGENHOFF, Editor, Geologic Branch	San Francisco
FENELON F. DAVIS, Geological Draftsman	San Francisco
MARY HELM, Geological Draftsman	San Francisco

* On leave for military service.

CONTENTS


INDEX MAP
OF
ECONOMIC MINERALS
IN
CALIFORNIA
AND THE
DISTRICTS OF THE DIVISION OF MINES
SCALE
0
50
100
200 MI.
CALIFORNIA STATE DIVISION OF MINES
1943
DISTRICT OFFICES OF THE DIVISION OF MINES
San Francisco (main office)
Los Angeles
Sacramento
Redding
BOUNDARIES OF THE DISTRICTS
OREGON
NEVADA
124°
123°
122°
121°
120°
119°
118°
117°
116°
115°
114°
42°
41°
40°
39°
38°
DEL NORTE
SISKIYOU
MODOC
HUMBOLDT
TRINITY
SHASTA
REDDING
LASSEN
TEHAMA
PLUMAS
GLENN
BUTTE
SIERRA
MENDOCINO
YUBA
NEVADA
LAKE
COLUSA
SUTTER
PLACER
EL DORADO
YOLO
SACRAMENTO
ALPINE
SONOMA
NAPA
AMADOR
SOLANO
CALAVERAS
MARIN
SAN JOAQUIN
MONO
TUOLUMNE
SAN FRANCISCO
CONTRA COSTA
ALAMEDA
STANISLAUS
MARIPOSA
SAN MATEO


ECONOMIC MINERALS
FUELS
GAS DISTRICT
OIL & GAS DISTRICT
METALS
CHROMITE
COPPER
GOLD DISTRICT
IRON
MANGANESE
QUICKSILVER
SILVER
TUNGSTEN
ZINC-LEAD
NON-METALS
ANDALUSITE & KYANITE
BARITE
BUILDING STONE
SANDSTONE
GRANITE
SLATE
CLAY
DIATOMITE
GEMS
GYPSUM
IODINE
LIMESTONE, CEMENT, MARBLE
MAGNESITE
MICA
PUMICE
SALINES
SOAPSTONE
SULPHUR
TALC
WOLLASTONITE
SANTA CLARA
MERCED
MADERA
SANTA CRUZ
FRESNO
INYO
SAN BENITO
TULARE
MONTEREY
KINGS
SAN LUIS OBISPO
KERN
SAN BERNARDINO
SANTA BARBARA
VENTURA
LOS ANGELES
ORANGE
RIVERSIDE
SAN DIEGO
IMPERIAL
MEXICO
ARIZONA
37°
36°
35°
34°
33°

ADMINISTRATION

ADMINISTRATIVE REPORT

By Walter W. Bradley, State Mineralogist

Personnel

Clyde McK. Laizure, associated with the California State Division of Mines for 26 years and, since July 1922, District Mining Engineer for the San Francisco District, died suddenly at his Alameda home on December 21. Pneumonia, complication of an attack of the epidemic influenza, was the cause ensuing a chill the night of December 17. Mr. Laizure was 65 years of age. Born in Ohio and brought up in North Dakota, he completed his technical education at the Missouri School of Mines. His engineering work has covered California, Nevada, and other States; and since his affiliation in 1917 with the California Division of Mines (known as the State Mining Bureau at that time) his writings for its official publications and his research work in the field have been of sterling value, making his death a heavy loss to the mining industry throughout the State. He is survived by his wife, Grace Laizure, his mother, Mrs. Mary V. Laizure, and brother, Captain Dallas C. Laizure, U. S. N.

Mr. Laizure was a member of Reading Masonic Lodge, Redding, California; of Alameda Chapter, R. A. M.; Alameda Commandery, K. T.; and of the American Institute of Mining and Metallurgical Engineers, San Francisco Chapter.

> Life is a mill and men the ore
> Roughest of rock may hold in store—
> The silver of love and gold of truth,
> Metals of strength and lasting youth.
> When I'm through and the cleanup is weighed,
> I hope there's an honest profit paid.
> May the millman speak not of laurels won,
> But simply say, " 'Twas a good mill run."
>
> Ramblin' Rufe,
> in *Mining and Industrial News*

Brigadier General Warren T. Hannum, U. S. A. Retired, was appointed, February 4, Director of the Department of Natural Resources by Governor Earl Warren. General Hannum graduated from West Point in 1902, served on the staff of General John J. Pershing in World War I, and won the Distinguished Service decoration. He has been a resident of San Francisco since 1938 while stationed as division engineer of the Army Engineer Corps for the Western States. During 1941-1942 he was also in charge of all army construction work in this area.

Miss Mary Helm was appointed a geological draftsman in the Division of Mines in November 1943. She studied at San Diego State College, San Diego, California, three years, finishing the fourth year at University of Missouri, majoring in geology.

New Publications

Since last noted, the following publication of the Division of Mines has been received from the State Printer and is now available at the offices of the Division:

CALIFORNIA JOURNAL OF MINES AND GEOLOGY

January 1943, being Chapter 1 of State Mineralogist's Report XXXIX. This chapter contains: *Organization and Service of the Division of Mines; Mines and Mineral Resources of Santa Cruz County; Discoveries in the Strategic Minerals, San Francisco Field District; Current Notes on Activities in the Strategic Minerals, Los Angeles Field District; Current Notes on Activity in the Strategic Minerals, Sacramento Field District; Current Notes on Activity in the Strategic Minerals, Redding Field District; Current Mining Activity in Plumas County;* also *Department of the Interior Information Service,* by the United States Geological Survey; *Accessions to the Exhibit; Review of California Mineral Production for 1942.*

GEOLOGIC BRANCH

CURRENT NOTES

By Olaf P. Jenkins*

In This Issue

The geology of large areas in the Mojave Desert is described in this issue of the JOURNAL by Professor William J. Miller, whose well illustrated papers on *Palm Springs, Blythe, Needles, Barstow,* and *Victorville* cover important regions of Riverside and San Bernardino Counties. The accompanying maps fill gaps, and in general improve the former compilation of the state geologic map of 1938.

New Publications

Bulletin 125 *Manganese in California* is now available. This book contains 387 pages, including many illustrations, a chart and a comprehensive index. *Economic Mineral Map No. 5, Manganese,* is folded in the pocket. Several authors, representing the United States Geological Survey, University of California, and Stanford University, as well as the Geologic Branch of the Division of Mines, have contributed to this book. Its contents are as follows:

In Press

One more step has been made toward publishing the areal geology of California by quadrangles; that is, geologic maps in colors printed on topographic base quadrangles of the United States Geological Survey. The first quadrangle-geology, recently published, is that of the San Benito quadrangle, appearing in the April 1943 issue of the JOURNAL. The next will be the Jamesburg quadrangle, Monterey County, with a report accompanying. The scale of the latter map is 1:62,500. The geology has been done by William Morris Fiedler, whose work represents a doctor's thesis accepted by the University of California.

* Chief Geologist, State Division of Mines.

GEOLOGY OF PALM SPRINGS-BLYTHE STRIP, RIVERSIDE COUNTY, CALIFORNIA

By William J. Miller *

OUTLINE OF REPORT

* Professor of Geology, University of California at Los Angeles. Manuscript submitted for publication January 17, 1944.

ABSTRACT

The Palm Springs-Blythe strip described in this report extends from the western base of San Jacinto Mountains eastward to the mountains facing the Colorado River. The strip is 120 miles in length, and it varies in width from 7 to 22 miles. On the accompanying maps the principal mountains and valleys are shown with their altitudes.

The oldest and most widespread rock complex, the Chuckwalla, is of early pre-Cambrian age. It is a complex of diorite and metadiorite, and a little older metasediment, cut to pieces, injected, and migmatized or digested by granitic material.

Next in age is the late pre-Cambrian Orocopia schist, consisting of metasediments, largely mica schist. It occurs in one large and several small areas between Palm Springs and Blythe.

The Palm Canyon complex is a Paleozoic or older metasedimentary-igneous complex extensively exposed south of Palm Springs and southeastward for 12 or 14 miles. It consists largely of crystalline limestones, quartzites, and mica schists or phyllites, cut and locally injected by dioritic, granitic, pegmatitic, and silexitic material. It is highly deformed.

One formation definitely known to be Paleozoic is the Maria formation, so named because of its occurrence in the Maria Mountains. It consists of crystalline limestone, gypsum beds, quartzites, and schists.

The Maria-plutonic complex, probably of Paleozoic age, also occurs in the Maria Mountains. It contains crystalline dolomitic limestones, quartzites and schists, cut by dioritic and granitic rocks, usually in the form of sills, and by many pegmatite dikes. The metasediments are much granitized and locally injected lit-par-lit by pegmatitic granite.

Hematite-bearing metasediments of probable Paleozoic age occur a few miles north-northwest of Eagle Mountain Camp. They mark the eastern end of the extensive "iron district" of the Eagle Mountains.

The McCoy Mountains formation is extensively exposed in the McCoy Mountains, the southern Coxcomb Mountains, and probably in the Palen Mountains. Most of this formation comprises metavolcanics, mainly original tuffs, together with some interbedded metasediments. It is thousands of feet thick, and it is either late Paleozoic or early Mesozoic in age.

Two intrusive formations, the Bradley granodiorite and the Fargo Canyon diorite, are not younger than late Jurassic or older than late Paleozoic. The Bradley granodiorite occurs in the Palm Springs-Indio area of the Palm Springs-Blythe strip. It varies from moderately foliated to highly foliated and granulated. It cuts the Palm Canyon complex, usually in the form of sills. The massive to moderately foliated Fargo Canyon diorite cuts the Chuckwalla complex sharply in the Little San Bernardino Mountains. The Fargo Canyon and the Bradley are probably correlatives.

Three important late Mesozoic intrusives are the generally massive San Jacinto granodiorite, the White Tank monzonite, and the Coxcomb granodiorite, so named from the areas in which they outcrop extensively. They are younger than any of the formations mentioned above, but they are probably of the same general age.

Quartz latite porphyry dikes and basic (andesitic) dikes of earlier Tertiary age occur at various localities from the Mecca Hills to the Maria Mountains.

Sedimentary formations of later Tertiary age include the marine Carrizo (or Imperial) formation which shows in the Indio Hills, and the Indio formation which shows extensively in both the Indio and Mecca Hills.

Quaternary alluvium is very widespread, and often hundreds of feet thick, in the wide desert basins lying between the mountains.

Most of the structural features of the Palm Springs-Blythe strip show a prevailing northwesterly trend, the principal exceptions being the Eagle Mountains and the valley just south of them. The mountains and valleys are without doubt largely or wholly tectonic in origin with faulting playing a very important role. The great San Andreas fault zone passes diagonally across the western part of the Palm Springs-Blythe strip.

GEOGRAPHIC AND RELIEF FEATURES

The strip of country described in this report extends from the base of the San Jacinto Mountains near Palm Springs eastward through the middle of Riverside County to the Maria Mountains facing the Colorado River north of Blythe.

This strip (Pls. I, II, III, IV) is 120 miles long, and ranges in width from a minimum of 7 miles east of Shaver Summit to a maximum of 22 miles in the Desert Center section. The base maps used are parts of topographic sheets prepared by the Metropolitan Water District of Southern California. Contours on the accompanying maps were taken from those sheets.

U. S. Highway 60-70, which extends through the strip, was used as the main base of operation for the field work. The principal towns are Palm Springs and Indio in the west, and Blythe in the east. Palm Springs is a famous desert winter resort. Smaller towns are Cathedral City, Coachella, and Thermal in the west, and Desert Center near the middle of the strip.

Altitudes within the mapped strip range from about 150 feet below sea level south of Thermal to about 4500 feet on the flank of San Jacinto Mountain near Palm Springs, and in the Cottonwood Mountains and Eagle Mountains. Rugged mountains rise steeply from 1000 to 3000 feet above adjacent lowland valley floors which have relatively smooth surfaces and gentle slopes. The broad, heavily alluviated valley floors comprise more than half the area of the strip. With a few small exceptions, the valley alluvium completely conceals the bedrock formations.

The whole mapped strip lies within the great desert region of southern California. Topographically the rugged mountains rising above the broad alluviated valleys represent stages varying from early maturity to late maturity in the desert cycle of erosion. More or less extensive and conspicuous alluvial fans nearly everywhere extend out from the mountain bases.

The principal mountains within the strip are indicated on the accompanying maps, and the contour lines show their general outlines and altitudes.

The principal valleys within the strip are Coachella, Chuckwalla, and Palo Verde. Coachella Valley, whose floor is about 450 feet above sea level near Palm Springs, is at sea level near Indio, and 150 feet below sea level south of Thermal. It continues southeastward beyond the map

limit to the Salton Sea which is about 245 feet below sea level. The vicinities of Indio, Coachella, and Thermal include a rich agricultural region, where date-growing is a specialty. Chuckwalla Valley extends for many miles from the Eagle Mountains to the McCoy Mountains. Its floor ranges in altitude from more than 1000 feet to less than 400 feet in a closed basin southwest of the McCoy Mountains.

Palo Verde Valley in the vicinity of Blythe, together with its wide northwestward extension between the McCoy and Maria Mountains, descends from an altitude of 800 feet in the northwest to about 250 feet at the Colorado River near Blythe. A rich farming district lies within Palo Verde Valley.

ACKNOWLEDGMENTS

Field work in the Palm Springs-Blythe strip was carried on at intervals, mainly during the cooler seasons from 1933 to 1942, as part of a program of study of the crystalline rocks of southern California. Much of the cost of field and laboratory work was defrayed by grants in aid from the Board of Research of the University of California, Los Angeles. This aid is gratefully acknowledged.

The writer wishes to thank officials and engineers of the Metropolitan Water District of Southern California for courtesies extended during the building of the Colorado River Aqueduct. Such courtesies included permission to make headquarters at Eagle Mountain Camp several times, and the privilege, on various occasions, of entering tunnels for the study of rocks while construction was in progress between the Little San Bernardino Mountains and the Coxcomb Mountains.

Certain fossil remains collected by the writer were sent for age determination to Dr. Winifred Goldring of the New York State Museum, Dr. G. Arthur Cooper of the United States National Museum, and Dr. Edwin Kirk of the United States Geological Survey. This aid is gratefully acknowledged.

Dr. Cordell Durrell of the Department of Geology, University of California, Los Angeles, helped with the interpretation of some of the thin sections.

PREVIOUS GEOLOGIC WORK

Surprisingly little has been published on the geology of the region, particularly on the kinds, origin, distribution, and age relations of the crystalline rocks which comprise the most varied and extensive bedrock formations.

Fraser's [1] geologic report on the San Jacinto quadrangle includes the extreme western part of the mapped strip in the vicinity of Palm Springs. Three formations mapped by him there are somewhat differently interpreted by the present writer.

In 1909 Mendenhall,[2] in a paper on the Indio region, described the sedimentary formations, particularly the water-bearing formations, and discussed the origin of the Salton Basin, including Coachella Valley. The crystalline rocks are very briefly mentioned in only general terms. No geologic map accompanies the paper.

---

[1] Fraser, Donald M., Geology of San Jacinto quadrangle south of San Gorgonio Pass, California: California Div. Mines Rept. 27, pp. 494-540, 1931.

[2] Mendenhall, Walter C., Groundwaters of the Indio region, California: U. S. Geol. Survey Water-Supply Paper 225, pp. 10-17, 1909.

Brown [3] published a paper in 1923 on a large region including the eastern two-thirds of Riverside County, all of Imperial County, and western San Diego County. Water supply of the region is emphasized, but pages 41-60 of the paper give observations by Brown and others on the geology. Only two of these pages are devoted to the pre-Tertiary crystalline rocks. Some geological notes are also given in other parts of the paper in connection with routes of travel, including the strip between Palm Springs and Blythe, especially pages 259 and 263. A small-scale reconnaissance geologic map accompanies the paper.

Tucker and Sampson [4] published a report in 1929 on the mines of Riverside County. Scattered through it are notes on kinds of rocks which contain the mineral deposits. Their geologic map of the eastern two-thirds of the county was taken from Brown's 1923 map.

In 1930 Buwalda [5] described the sedimentary formations of the Indio Hills and discussed the origin of the Salton Basin, including Coachella Valley.

Woodring [6] has discussed the age of the marine beds of the Indio Hills.

Darton's [7] guidebook for the Southern Pacific Lines contains a geologic map (sheet 27) accompanied by geologic notes (pp. 257-263) on the Coachella Valley region. Most of this material is taken from the earlier work by J. S. Brown; some of it from the work of D. M. Fraser; and the mapping of principal faults is credited to L. F. Noble.

A report on the iron ore of the Eagle Mountains was published by Harder [8] in 1912. Only a small part of the area described comes within the Palm Springs-Blythe strip of the present report.

Hazzard, Gardner, and Mason [9] suggest an early Mesozoic age for the metasediments and associated metavolcanics in the Coxcomb Mountains.

In 1910 Harder [10] reported on the gypsum deposits and associated rocks in the Palen Mountains some miles north of the Palm Springs-Blythe strip of the present paper.

Hess [11] has very briefly described the gypsum-bearing strata of the Little Maria Mountains.

That part of the Geologic Map of California (1938) involving the Palm Springs-Blythe strip, is, in the main, much like Brown's 1923 reconnaissance geologic map already mentioned.

---

[3] Brown, John S., The Salton Sea region, California: U. S. Geol. Survey Water-Supply Paper 497, 1923.

[4] Tucker, W. B., and Sampson, R. J., Riverside County: California Div. Mines Rept. 25, pp. 468-526, 1929.

[5] Buwalda, John P., and Stanton, W. Layton, Geological events in the history of the Indio Hills and the Salton Basin: Science, new ser., vol. 71, pp. 104-106, 1930.

[6] Woodring, Wendell P., Distribution and age of the marine Tertiary deposits of the Colorado Desert: Carnegie Inst. Washington Pub. 148, pp. 1-25, 1932.

[7] Darton, Nelson H., Guidebook of the western United States, pt. F, Southern Pacific Lines: U. S. Geol. Survey Bull. 845, 1933.

[8] Harder, Edmund C., Iron-ore deposits of the Eagle Mountains, California: U. S. Geol. Survey Bull. 503, 1912.

[9] Hazzard, John C., Gardner, Dion L., and Mason, John F., Mesozoic (?) metavolcanic and sedimentary rocks in San Bernardino and Riverside Counties, California: Geol. Soc. America, Proc. 1937, p. 279, 1938.

[10] Harder, Edmund C., Gypsum deposits of the Palen Mountains, California: U. S. Geol. Survey Bull. 430, pp. 407-416, 1910.

[11] Hess, Frank L., in Gypsum deposits of the United States: U. S. Geol. Survey Bull. 697, pp. 78-79, 1920.

EARLY PRE-CAMBRIAN ROCKS

Chuckwalla Complex

General Description

The Chuckwalla complex, so named because of the excellent exposures in the Chuckwalla Mountains, comprises a mixed lot of crystalline rocks, the components of which are usually too intimately associated to be mapped separately. The Chuckwalla is an igneous-metamorphic complex, the most extensive within the Palm Springs-Blythe strip.

The chief constituents of the Chuckwalla complex are dark-gray to nearly black hornblende-rich diorite which grades into metadiorite; crudely foliated, usually contaminated, pinkish-gray granite which grades into granodiorite; and some local metasediments. From oldest to youngest they are metasediments, diorite, and granite.

The dioritic rocks have been so thoroughly cut to pieces by the distinctly younger granitic rocks that only numerous irregular remnants of them remain. These remnants usually range from a few inches to several hundred feet in length. Thus the two rocks form a complex with dioritic material predominating in some places, and granitic material in others. In part the diorite is massive to only crudely foliated, and but little granite-soaked or granite-injected. In most places, however, strongly foliated to even schistose metadioritic facies of the diorite have been granite-soaked or granite-injected, and migmatites and crudely banded gneisses have resulted (fig. 2). Occasionally, small irregular angular masses of the nearly pure dark-colored undigested diorite are left in the migmatites. These do not have sharp contacts. In still other places the metadiorite has been so injected in lit-par-lit fashion as to produce well-banded gneisses. In the few places where associated metasediments are known to have been injected lit-par-lit by the granite, well-defined banding occurs. The banded structures, with alternating layers from a small fraction of an inch to several inches or more in width, may be well defined, straight and fairly regular, or locally contorted, or crudely developed. The bands often are distinct and sharply defined, but more often they are less distinct, with blurred borders. The usually pinkish-gray granitic material, even where it predominates notably, is almost everywhere contaminated with dioritic material. The crude foliation of the medium- to moderately coarse-grained impure granite is accentuated by a rough parallelism of the mafic minerals. In some areas, pegmatitic and aplitic dikes, representing late derivatives of the granite magma, cut the earlier-formed mixed rocks, in many cases transecting the foliation. One facies of the Chuckwalla complex is a porphyritic gneiss which occurs in localized zones. It is probably a granite-diorite syntectic (fig. 3).

Occurrences

Cottonwood and Little San Bernardino Mountains. The Chuckwalla of the Cottonwood Mountains and adjacent southeastern part of the Little San Bernardino Mountains corresponds with the complex as described above, with the single exception that little if any metasedimentary material has been positively recognized. A thin section of the typical little-affected diorite from the Little San Bernardino Mountains shows by volume percentages: plagioclase (andesine-labradorite), 60;

hornblende, 34; quartz, 5; apatite, $\frac{3}{4}$; and magnetite, $\frac{1}{4}$. It is equigranular, medium-grained, and hypidiomorphic. Another section of the diorite from the same region shows more quartz, much less hornblende, and considerable biotite. This rock is distinctly foliated. A thin section of the pure granite from the Chuckwalla complex in the Little San Bernardino Mountains some miles north of the Palm Springs-Blythe strip shows by volume percentages: orthoclase, 42; quartz, 35; oligoclase, 20; hornblende, $1\frac{1}{2}$; biotite, $\frac{1}{2}$; magnetite, $\frac{1}{2}$; titanite, $\frac{1}{4}$; allanite, $\frac{1}{4}$; and a little zircon. The rock is medium-grained, equigranular, and allotriomorphic.

Shaver Summit and Desert Center Region. Rocks in all important respects typical of the Chuckwalla complex as already described, occur as shown on the accompanying geologic maps (Pls. II and III) in the general vicinities of Shaver Summit, Eagle Mountain Camp, and Desert Center, including the typical occurrences in the Chuckwalla Mountains. Detailed descriptions are therefore not necessary, but a few items of importance will be mentioned. Little if any positively recognizable metasedimentary material has been found associated with these rocks. Aplite and pegmatite dikes, representing satellitic offshoots of the granite, cut the diorite-granite mixed rocks. Good examples occur in the vicinity of Eagle Mountain Camp, and near the highway 4 miles east of Desert Center. A conspicuous belt or lens of the old metadiorite occurs as part of the Chuckwalla complex on the north side of the little valley 3 miles southwest of Eagle Mountain Camp. It is two-thirds of a mile long, about 200 yards wide, and strikes west-northwest. It lies within foliated granite contaminated with dioritic material. Nearly every stage and kind of gradation produced by injection and digestion of dioritic material by granite magma can be seen. A thin section of unaltered diorite from the ridge of diorite-granite mixed rocks $2\frac{1}{2}$ miles south-southeast of Eagle Mountain Camp contains the following volume percentages of minerals: andesine, 56; hornblende, 40; magnetite, $2\frac{1}{2}$; titanite, $\frac{3}{4}$; epidote, $\frac{3}{4}$; and a little apatite. It is medium-grained, dark gray, granitoid, and allotriomorphic. Another specimen of the diorite from the same vicinity is more acidic, probably because of reaction with granitic material. It shows: oligoclase-andesine, 65; quartz, 28; biotite, 5; epidote, $1\frac{1}{2}$; and small amounts of magnetite, zircon, apatite, and sericite. The medium-grained rock has a fine granular groundmass between the quartz and feldspar grains. A thin section of the typical purer granite from 3 miles southwest of Eagle Mountain Camp shows by volume percentages: quartz, 30; orthoclase, 30; oligoclase, 25; microcline, 12; hornblende, $1\frac{1}{2}$; magnetite, $\frac{3}{4}$; epidote, $\frac{1}{2}$; allanite, $\frac{1}{4}$; and very little apatite and zircon. It is highly granulated and strongly foliated; general orientation of the crushed minerals is parallel to the foliation. A section of a specimen from a mile farther south, and another from granite near the highway 4 miles east of Desert Center, are much like the section just described, but they are less strongly foliated, and they contain 8 percent and 1 percent of biotite respectively. Two thin sections from the Chuckwalla complex $2\frac{1}{2}$ miles south-southeast of Eagle Mountain Camp show the rocks to be granodiorite rich in microperthite and lacking in orthoclase. A thin section of somewhat contaminated granite from the Chuckwalla complex 3 miles west-northwest of Eagle Mountain Camp shows: orthoclase (some perthitic), 34; quartz, 20; oligoclase, 20; fine granular material, prob-

ably quartz and feldspar, 20; biotite, 5; epidote, $\frac{3}{4}$; and small amounts of allanite and zircon. The rock is holocrystalline, inequigranular, crudely foliated, and much sheared and granulated.

At various places within the diorite-granite mixed rocks of the Chuckwalla complex, there are local occurrences of genetically associated porphyritic gneisses. There are good examples on the side of the ridge extending westward for $2\frac{1}{2}$ miles from Eagle Mountain Camp, and on the ridge $2\frac{1}{2}$ miles south-southeast of that Camp, where numerous inclusions of diorite and strongly foliated strips of metadiorite of various sizes occur in the crudely foliated, usually contaminated granite, and to some extent in the porphyritic gneiss. Borders of the xenoliths vary from fairly sharp to very blurred. All stages of assimilation or digestion of dioritic material by the granite may be oberved. Thorough digestion resulted in a syntectic magma from which the porphyritic gneiss developed. Light flesh-colored anhedral to subhedral phenocrysts of potash feldspar, as much as an inch in length, are set in a dark-gray vari-grained crudely foliated groundmass rich in plagioclase and mafic minerals. The texture is not that of a typical plutonic rock. It lacks uniformity in composition, degree of foliation, and size and distribution of phenocrysts. Somewhat similar rocks have been found by the writer in various parts of southern California, good examples being in the Marble Mountains along Highway 66 north of Cadiz, in the Bristol Mountains a few miles east of Amboy where it cuts highly crystalline metasediments, in the Old Woman Mountains between Essex and Chubbuck, in the Pinto Mountains near Twenty-nine Palms,[12] in the Piute Mountains and Homer Mountains,[13] and in the Maria Mountains. Observations in these and other places have led the writer to conclude that the porphyritic gneisses are granite-diorite syntectic products.

Blythe Region. The Mule Mountains consist largely of diorite-granite mixtures representing all important facies of the typical Chuckwalla complex. Granite cuts the diorite and metadiorite and intrudes them, producing lit-par-lit structures. About 2 miles south of the geologically mapped portion of these small mountains, the rocks are prevailingly light-gray, massive to distinctly foliated granite which is much less intimately associated with the diorite. This granite contains a good many irregularly distributed belts and patches of diorite, in part schistose, reaching 30 or 40 feet in width and 200 yards in length. These inclusions of diorite in granite are usually straight and deceivingly dikelike in appearance. The schistose parts are either small patches or borders of the larger masses, the foliation having been caused by pressure of the enclosing granite. Very locally the metadiorite shows some lit-par-lit structure, the result of injection by the granite. In the Mule Mountains there are, therefore, all gradations between dioritic masses which were relatively little affected by granitic magma, and those in which the two rocks form very confused and intimate mixtures. Some metasediments are probably associated with the diorite-granite mixture, as shown by the finding of many rounded pebbles of hard quartzite in a wash at the east base of the mountains $1\frac{1}{2}$ miles south of the mapped portion.

---

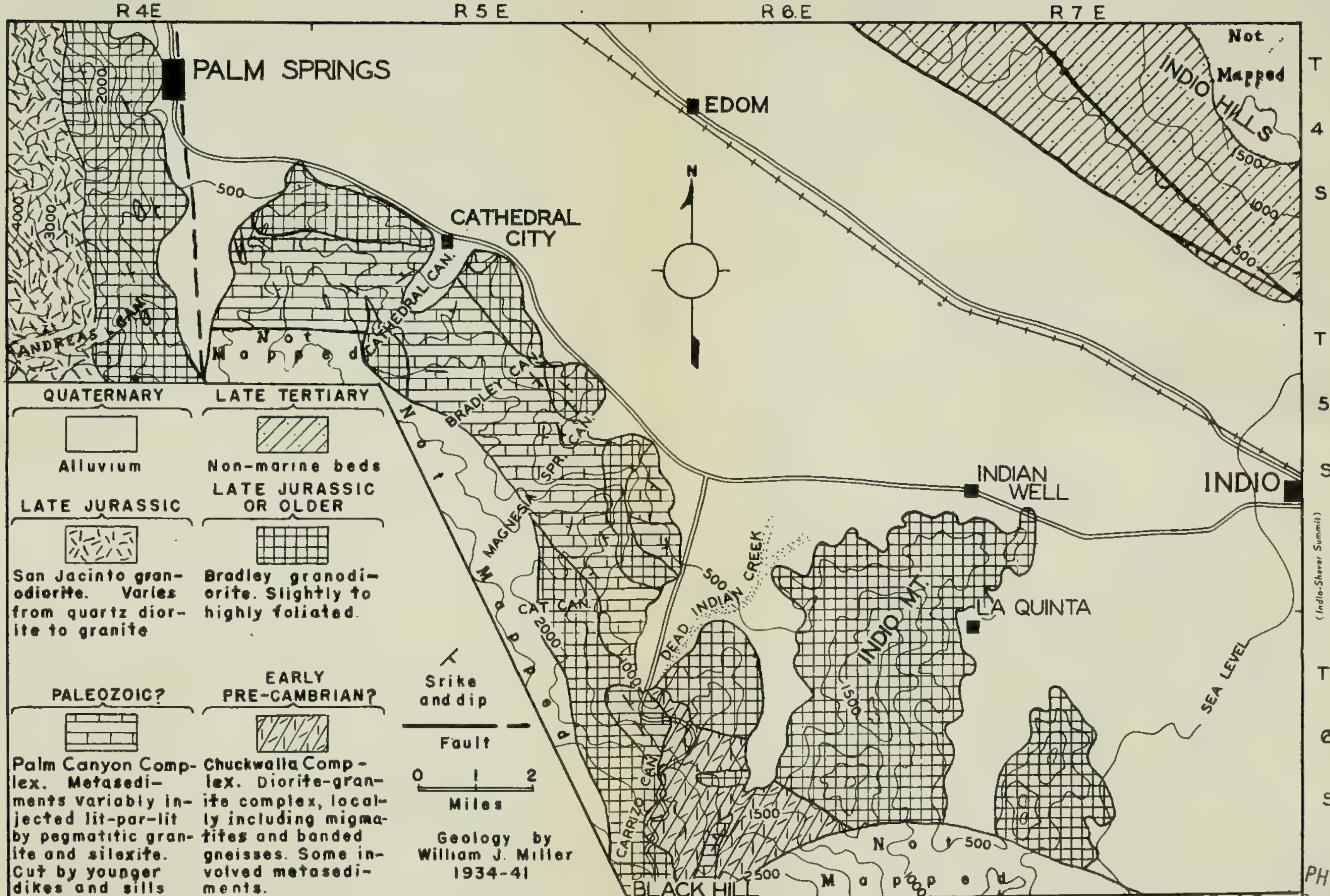
[12] Miller, William J., Pre-Cambrian and associated rocks near Twenty-nine Palms, California: Geol. Soc. America Bull., vol. 49, pp. 433-435, 1938.

[13] Miller, William J., Geology of the Needles-Goffs region, California: California Div. Mines Rept. 40, pp. 113-129, 1944.

DIVISION OF MINES
WALTER W. BRADLEY STATE MINERALOGIST
OLAF P. JENKINS CHIEF GEOLOGIST

STATE OF CALIFORNIA
DEPARTMENT OF NATURAL RESOURCES

PLATE I



ACCOMPANYING STATE MINERALOGIST'S REPORT XL, JANUARY, 1944

CONTOUR LINES FROM U. S. G. S. INDIO AND SAN JACINTO QUADRANGLES

GEOLOGIC MAP OF THE PALM SPRINGS-INDIO AREA, CALIFORNIA

The greatest development of the Chuckwalla complex in the Blythe area is in the Maria Mountains. It is extensively exposed in the geologically mapped southeastern two-thirds of these mountains (pl. 4). This area shows many of the features typical of the Chuckwalla complex farther to the west as already described, but some features are of special interest. The southeastern 8 or 10 square miles of the mapped area of the formation, facing the Colorado River, consists largely of pinkish-gray moderately coarse-grained crudely foliated granite. This granite is somewhat variable in composition and texture, in places becoming pegmatitic. Locally it contains inclusions of metadiorite in lens-shaped masses ranging up to 75 feet in width and 100 yards in length. A thin section made from the granite near the road 9 miles north-northeast of Blythe is of unusual interest. It contains by volume percentages: microcline, 50; quartz, 22; albite, 20; muscovite, 4; magnetite, $2\frac{1}{2}$; biotite, $1\frac{1}{2}$; and a few tiny grains of allanite. Much of the albite occurs as irregular-shaped, partial replacements of large microcline crystals, but there are some fairly large individual albites. There are also many replacing veinlets of quartz in the form of tiny grains; some veinlets of quartz and magnetite; and some of quartz and muscovite in the form of tiny grains and flakes. These veinlets cut into and across both microcline and albite. There are some large quartz individuals. The section is very inequigranular.

Several square miles of the middle part of the mapped area of the Chuckwalla complex, 8 to 11 miles north of Blythe, consist of diorite and metadiorite cut to pieces and locally digested by light-gray, crudely foliated granite. A considerable portion of this mixture is a porphyritic gneiss with subhedral flesh-colored potash feldspars, as much as an inch in length, in a massive to crudely foliated dark-gray, medium-grained matrix. Little banded gneiss shows in this area. Most of the granite is contaminated, and there are many remnants of the diorite and foliated metadiorite ranging in size from tiny shreds to many feet in length and several feet in width. These are undigested parts of the diorite, but in numerous places every stage in the assimilation of dioritic material by the granite may be seen. Rather thorough digestion produced syntectic magma from which the porphyritic gneiss crystallized, as in the vicinity of Eagle Mountain Camp. Many dikes of aplitic granite cut the porphyry without very sharp contacts.

Seven-Level Hill Area. Though the rock series of the Seven-level Hill area is mapped as Chuckwalla complex, there is some question as to its age. After considerable search, the writer was unable to find a sharp contact between this body and the Palm Canyon complex adjacent on the northwest (Pl. I). Accordingly, this body of probable Chuckwalla could represent a facies of the Palm Canyon complex in which but little metasedimentary material occurs. If so, it is either Paleozoic or older. It is, however, possible that the Palm Canyon sediments were deposited unconformably upon an old complex (Chuckwalla) and the contact blurred beyond recognition by the Palm Canyon and/or post-Palm Canyon intrusives of the region. If so, the complex of Seven-level Hill is to be classed with the early pre-Cambrian Chuckwalla complex. In any case, the Chuckwalla of Seven-level Hill has nearly all the characteristics of the Chuckwalla complex as already described.

An excellent opportunity to study the Chuckwalla of the Seven-level Hill area is afforded by the deep road cuts along the winding mountain grade (Seven-level Hill) $8\frac{1}{2}$ to 11 miles south-southeast of Cathedral City (fig. 4). Some highly metamorphosed sediments including quartzites, schists, and some crystalline limestones, are cut by dark-gray hornblende-rich diorite; the metasediments and diorite are cut by granite; and some pegmatitic and granitic dike facies of the granite cut the combination. Toward the bottom of the Seven-level Hill grade, metasedimentary material occurs in considerable quantity in the complex, but there is little definitely recognizable old diorite and metadiorite. Banded injection gneisses are common and there are some crudely porphyritic facies, but contaminated granite, varying to pegmatitic granite, and various digestion products or syntectics, resulting from attack of the granite magma upon the older rocks, predominate.

Along the middle and upper parts of the grade within the Chuckwalla complex, metasedimentary material is little, if at all, in evidence and old dioritic material is abundant. This older diorite should not be confused with the much younger Bradley granodiorite which cuts the Chuckwalla of Seven-level Hill at several places along the grade.

Structure and Age

Because the structure of the Chuckwalla complex is exceedingly variable, even very locally so, few foliation strike and dip symbols are plotted on the accompanying geologic maps. Dips range from nearly flat to vertical with most of them by far steeper than 40°. There is some tendency toward a very general westerly to northwesterly trend of strike of foliation. The internal structure of the formation is usually so indefinite, irregular, or complex that an attempt to work it out in detail, with the inadequate available maps, would be a difficult, if not impossible, undertaking.

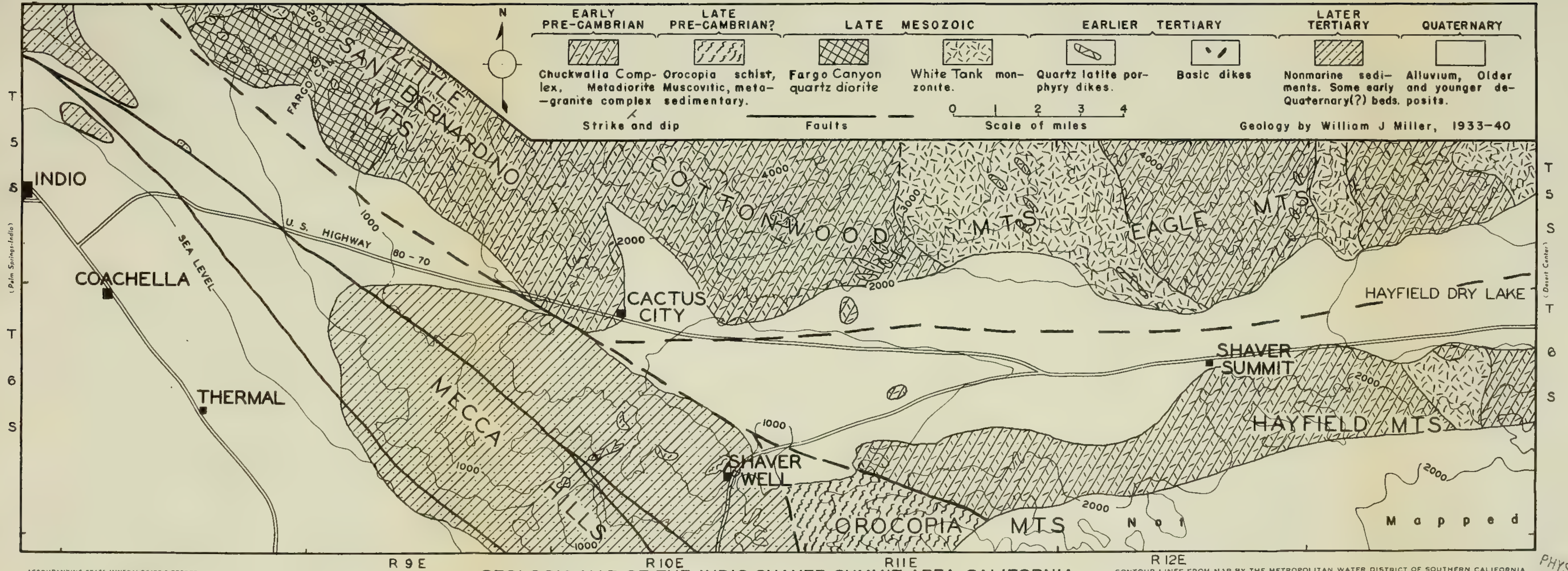
The Chuckwalla complex is regarded as early pre-Cambrian in age, like similar combinations of rocks not only in other parts of southern California, but also in many parts of the world. The high degree of metamorphism of the rocks and the abundance of lit-par-lit injection gneisses suggest the great age. Rocks of probable late pre-Cambrian age in Arizona and the southern half of California are petrologically very different, consisting mainly of metasediments usually only moderately altered and not extensively cut to pieces or injected by granitic rocks. The Vishnu schist of the Grand Canyon, much like the Chuckwalla complex, is definitely older than these late pre-Cambrian rocks. Lee [14] mentions the occurrence of a pre-Cambrian complex of biotite granite, granite-gneiss and schist, and metamorphic sediments in the Buckskin Mountains about 50 miles northeast of the Maria Mountains. The Chuckwalla complex is, in most respects, like early pre-Cambrian formations previously described by the writer, including the San Gabriel formation [15] of the San Gabriel Mountains; the Pinto gneiss [16] near Twenty-nine Palms; and the Needles formation [17] of the Needles-Goffs region.

[14] Lee, Willis T., Geologic reconnaissance of a part of western Arizona: U. S. Geol. Survey Bull. 352, p. 29, 1908.
[15] Miller, William J., Geology of the western San Gabriel Mountains of California: Univ. California at Los Angeles, Pub. Math. and Physical Sci., vol. 1, pp. 49-56, 1934.
[16] Miller, William J., op. cit., pp. 424-427, 1938.
[17] Miller, William J., op. cit., pp. 116-119, 1944.

DIVISION OF MINES
WALTER W. BRADLEY, STATE MINERALOGIST
OLAF P. JENKINS, CHIEF GEOLOGIST

STATE OF CALIFORNIA
DEPARTMENT OF NATURAL RESOURCES

PLATE II



ACCOMPANYING STATE MINERALOGIST'S REPORT XL, JANUARY 1944

GEOLOGIC MAP OF THE INDIO-SHAVER SUMMIT AREA, CALIFORNIA

CONTOUR LINES FROM MAP BY THE METROPOLITAN WATER DISTRICT OF SOUTHERN CALIFORNIA

In the Maria Mountains of the Palm Springs-Blythe strip, the Paleozoic Maria formation rests unconformably upon the Chuckwalla complex. In the Marble Mountains north of Cadiz, and in the Old Woman Mountains 6 miles southeast of Fenner [18] Cambrian strata rest by profound unconformity upon rocks similar to the Chuckwalla complex. The Triassic or older McCoy Mountains formation of the present report is certainly much younger than the Chuckwalla complex as shown by the great difference in degree of metamorphism.

LATE PRE-CAMBRIAN ROCKS

Orocopia Schist

The Orocopia schist is so named because of the excellent exposures in the northwestern part of the Orocopia Mountains, 5 or 6 square miles of which consist of the schist within the Palm Springs-Blythe strip (Pl. II). The schist extends southward into the mountains, but its full extent was not determined by the writer. The only other occurrences within the strip are three much smaller masses protruding through late Tertiary beds in the eastern part of the Mecca Hills, as shown on the geologic map.

Muscovite schists are by far the most abundant rocks of the formation, biotite schists are less common. Interbedded biotite-muscovite-quartz-feldspar schists are fairly common as are also muscovitic, calcareous, quartzitic schists. There are also some beds of biotitic quartz schist, and thin-bedded nearly pure fine-grained crystalline limestone and arenaceous limestone. The whole well-bedded formation is metasedimentary. Because of the nature of the rocks, the outcrops, from a little distance, present a somber appearance.

In the Orocopia Mountains the Orocopia-Chuckwalla contact for about 2 miles is concealed, but 2 or 3 miles back in the mountains the schist was found sharply faulted against the Chuckwalla complex. Although the original contact between the two was not found, the Orocopia schist is without doubt younger than the Chuckwalla because it is less metamorphosed and contains none of the intrusive rocks which constitute the bulk of the adjacent Chuckwalla complex.

The Orocopia schist is almost exactly like the late pre-Cambrian Pelona schist of Los Angeles County and is probably the same age. There is, of course, the possibility of a still younger age.

PALEOZOIC OR OLDER ROCKS

Palm Canyon Complex

General Statement

The Palm Canyon complex is here so named because of typical exposures on the east side of lower Palm Canyon. It consists largely of metasediments, including much crystalline limestone, quartzite, and mica schist. These metasediments are in many places so intimately cut and locally injected with dioritic, granitic, pegmatitic, and silexitic material as to make unsatisfactory any attempt to map separately these mixed rocks (fig. 5). The whole complex is so highly deformed and

[18] Hazzard, John C., and Dosch, Earl F., Archean rocks in the Piute and Old Woman Mountains, San Bernardino County, California: Geol. Soc. America, Proc. 1936, p. 309, 1937.

contorted, with so many local variations in strike and dip, that any attempt to work out even the broad features of the stratigraphy would be difficult (fig. 6). There is perhaps a general northwesterly strike, and dips are usually steep. The complex is known to be many hundreds of feet thick, and may be several thousand feet thick.

Description of Areas

Rocks characteristic of the Palm Canyon complex, excellently exposed in and around Cathedral Canyon, may be considered in three categories: (1) metasediments, which greatly predominate; (2) igneous rocks, including diorite, granite, pegmatite, and silexite; and (3) many local developments of more or less intimate mixtures of the metasedimentary and igneous rocks, including granitization products, and lit-par-lit injection gneisses. Bedding is usually fairly well preserved in the metasediments, and the igneous rocks and mixtures show a strong tendency to follow the bedding.

(1) Most abundant among the metasediments are the crystalline limestones. These are very fine-grained, with variations to finer medium-grained. Most are white, some are light bluish gray, and fewer are light brown. All, or nearly all, are calcitic. Very commonly the limestones seem to have been granitized or silicified as shown by the presence of scattering very small, usually roundish grains of silica, and fewer lens-like and irregular-shaped, angular to fairly well-rounded bits of granite, as much as an inch in length. These granite fragments are from bands of injected granite which have been broken up and the pieces kneaded into the plastic limestone. In a few cases thin, unbroken bands of granite are in contact with limestone. Quartzites and quartz schists are also abundant. Most of them are light-gray, fine- to medium-grained, biotitic, and highly foliated with the larger quartz grains well flattened; but some of the finer-grained ones, with little biotite, are only slightly foliated. Most of these quartz-rich rocks are granitized or injected lit-par-lit. Some mica schists occur, such as a highly foliated, biotite-rich, quartz-feldspar-garnet schist, but they are not common. Evidently the original sediments of the Palm Canyon complex were limestones, sandstones, argillaceous sandstones, and some shales.

(2) A diorite, not to be confused with the distinctly later Bradley granodiorite, is the oldest igneous rock of the Palm Canyon complex. It varies from a medium- to moderately fine-grained, dark-gray, massive, hornblende-rich rock to strongly foliated, biotite-rich meta-diorite, the latter usually being variably granitized parallel to the foliation. The diorite nearly always intrudes the strata in the form of thin sills, seldom more than a few feet thick. In some places it is cut irregularly by dikelets of granite. This dioritic material is very subordinate. Granite, pegmatitic granite, pegmatite, and silexite are fairly common throughout the formation, characteristically cutting the older rocks parallel to the bedding. These rocks show all transitional facies from one to another. There is a good deal of silexite, some of it being white, fine-grained nearly pure silica, but much of it containing 5 to 10 percent of small scattering potash feldspars arranged parallel to a crude foliation. Pegmatitic granite is also fairly common. It varies from massive to crudely foliated, and from pinkish gray to light gray. It is

often biotitic. Most of the acidic intrusives are contaminated with country rock. The intrusive rocks of group 2 just described are so closely and widely associated with the metasediments of the Palm Canyon complex that any attempt to map them separately would be hopeless.

(3) The mixed rocks consist of metasediments and small diorite sills cut, digested, and injected lit-par-lit by granitic, pegmatitic, and silexitic material. In many local zones the acidic magmas have so thoroughly granitized, silexitized, digested, injected lit-par-lit, or replaced the biotitic quartzites, schists, and metadiorite in the sills that various syntectics and banded gneisses have been produced (fig. 7). In some zones parallel to bedding and foliation, well-banded gneisses consisting of thin dark-gray layers of metadiorite and biotitic quartzite have been much injected lit-par-lit, and somewhat digested, by silexite and pegmatitic silexite, so that both diorite and quartzite have almost lost their identities as such (fig. 8). In still other zones, magmatic penetration, digestion, and replacement have been almost complete, leaving only ghostlike remnants of the practically unrecognizable older rocks in the acidic intrusives. Excellent exposures of the mixed rocks occur 2 miles south of Cathedral City, where silexite and pegmatitic silexite were the replacing agents. It is interesting to note that the abundant purer crystalline limestones very largely escaped penetrative attack by the acidic magmas. However, some silica in the form of small roundish grains in many of the limestones was introduced magmatically. Some small unmapped sills of the Bradley granodiorite, and the still later San Jacinto granodiorite, cut the Palm Canyon metasediments and associated igneous rocks.

Rocks very similar to those just described as occurring in the type region also comprise the large area of the Palm Canyon complex as mapped (Pl. I) between Cathedral Canyon and Dead Indian Creek. Crystalline limestones, locally dolomitic, are the predominant rocks, but biotitic and quartzitic schists are somewhat more common than in the Cathedral Canyon area, and graphite flakes were noted in the limestone. Some small unmapped sills and dikes of the distinctly younger Bradley granodiorite, and the still later San Jacinto granodiorite cut these metasediments and associated mixed rocks.

The exposure of Palm Canyon complex extending across Dead Indian Creek and lower Carrizo Creek shows mainly granite and silexite-injected, well-bedded metasediments together with some diorite. Migmatite, well-banded gneiss, foliated impure granite, pegmatitic granite, silexite, and intercalated beds of crystalline limestone, quartzite, and mica schist constitute the bulk of the rocks. Bedding, foliation, and intrusions are nearly always parallel. The limestones, both white and bluish gray, often contain small, roundish grains of silica and, more locally, small angular to rounded bits of granite like those described from the limestone of the Cathedral Canyon area. Lit-par-lit injection by pegmatitic granite and silexite has, in some zones, replaced 50 percent or more of the sedimentary material parallel to the bedding. Along Carrizo Creek, granitization of mica schists and quartz schists has produced crude porphyroblastic schists with irregularly scattered metacrysts. Various small unmapped sills of foliated Bradley granodiorite, and still later granite and pegmatite, cut the metasediments and metasedimentary-igneous mixtures. Careful search failed to locate any sharp contact

between the Palm Canyon complex of this area and the adjacent Chuckwalla complex of Seven-level Hill. There is, therefore, the possibility that in this region the Chuckwalla complex is a facies of the Palm Canyon complex in which occurs but little metasedimentary material.

The small body mapped northeast of Black Hill shows rocks similar to those already described, but no detailed examination of it was made.

The Palm Canyon complex is the same as Fraser's [19] ''metamorphic series'' in regard to which he says:

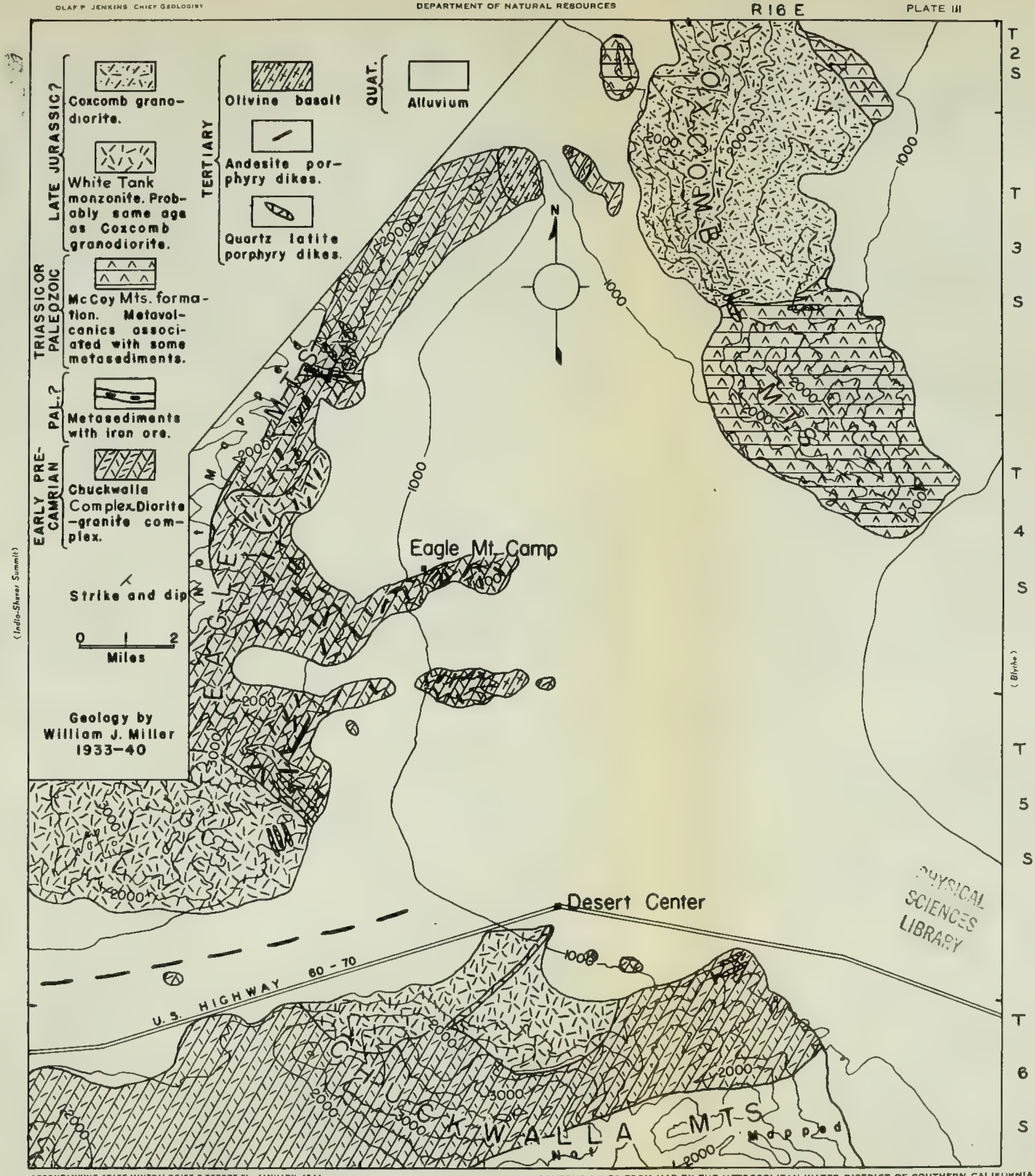
"A great series of undifferentiated schists is well exposed in the eastern wall of Palm Canyon * * * Crystalline limestone, quartzite, biotite-feldspathic schist, hornblende schist, mica schist, injected schists, and well-banded granitic gneisses make up the series."

On page 538 of Fraser's report, two sketches indicate older (Paleozoic?) igneous rocks cutting the sediments before the intrusion of his Jurassic ? plutonics, but he neither describes them nor represents them on his geologic map. The present writer agrees with Fraser in regard to the occurrence and probable age of such older igneous rocks. Fraser (pp. 534-536) describes some of the schists and gneisses of his metamorphic series (the author's Palm Canyon complex), and concludes that his granitic gneisses cannot definitely be assigned to a former igneous or sedimentary origin. He neither mentions the common occurrence of granite, pegmatitic granite, pegmatite, and silexite in the metamorphic series, nor discusses the origin of his injected schists. He believes that his metamorphic series was metamorphosed by dynamo-thermal action without introduction of magmatic materials, citing the absence of minerals usually found in rocks resulting from plutonic or thermal metamorphism.

The present writer has already presented evidence showing that not only the crystalline limestones and quartzites, but also many of the schists, of the metamorphic series (Palm Canyon complex) are true metasediments; that many of the so-called granitic gneisses are of igneous origin; that granite, pegmatitic granite, pegmatite, and silexite are widely and intimately associated with the metasediments; and that these acidic intrusives have, in many places, injected the metasediments lit-par-lit thus giving rise to the injection schists and gneisses, while in other places they have almost completely replaced zones of the metasediments. As pointed out beyond, these acidic intrusives are definitely older than both the Bradley granodiorite and the San Jacinto granodiorite. Finally, the pegmatitic and silexitic magmatic materials were introduced at relatively low temperatures above the main body of a batholith, and hence typical plutonic minerals would not necessarily be expected.

Outside of the mapped area of the present report, there are excellent exposures of the Palm Canyon complex in large road cuts along the highway 5 and 7 miles northwest of Palm Springs. These rocks are mainly steep-dipping metasediments, including biotite schists interbedded with some crystalline limestone and quartzite. The schists have been locally more or less granite-injected lit-par-lit. This combination of rocks, like those of the other areas above described, is cut by some unmapped sills or dikes of the Bradley granodiorite and the San Jacinto granodiorite.

[19] Fraser, Donald M., op. cit., pp. 504-507, 1931.



ACCOMPANYING STATE MINERALOGIST'S REPORT XL JANUARY, 1944
CONTOUR LINES FROM MAP BY THE METROPOLITAN WATER DISTRICT OF SOUTHERN CALIFORNIA

GEOLOGIC MAP OF THE DESERT CENTER AREA, CALIFORNIA

Age of the Complex

A few specimens of the limestone found by the writer on the mountain between Bradley and Cathedral Canyons contain what may possibly be poorly preserved and replaced crinoidal fragments of Paleozoic age. Dr. G. Arthur Cooper of the United States National Museum thinks that they probably are, but he warns against determination of such fragmentary and poorly preserved material. Several other paleontologists very much doubt even an organic origin of the material. The fact that the fragments in question consist of feldspar renders their organic origin unlikely because such mineral replacement would, to say the least, be unusual.

The older dioritic, granitic, pegmatitic, and silexitic rocks which penetrate the Palm Canyon metasediments are younger than the limestone, possibly late Paleozoic. In any case these intrusives are definitely older than the Bradley granodiorite, and much older than the massive granite and granodiorite of the San Jacinto batholith which is no doubt late Mesozoic.

The strata of the Palm Canyon complex must have been metamorphosed before the entry of the San Jacinto granodiorite into them because, as Fraser says (p. 507), their degree of metamorphism is not noticeably more intense near the contact than it is some miles away. Also offshoots of the batholith cut the lit-par-lit injected sediments sharply.

It may also be noted that the known Triassic strata of various places in southern California, such as the vicinities of Winchester and Elsinore, are distinctly less metamorphosed than the Palm Canyon metasediments, and they are not intimately and widely penetrated lit-par-lit by the nearby late Mesozoic acidic intrusives.

In conclusion, the Palm Canyon complex is considered to be Paleozoic or older.

PALEOZOIC ROCKS

Maria Formation

Occurrences in the Little Maria Mountains

The name Maria formation is here proposed because of the typical occurrence of the formation in the Maria and Little Maria Mountains. Gypsum obtained from the formation in the southern part of the Little Maria Mountains, and the northwestern part of the Maria Mountains, supports an important mining industry. The principal workings are west and southwest of Midland in the Little Maria Mountains, where an area of several square miles is underlain by beds of gypsum. The gypsum deposits of this area were described briefly by Surr [20] in 1911; by Hess [21] in 1920; and by Tucker and Sampson [22] in 1929. West of Midland the formation consists of crystalline limestone with interbedded gypsum, schist, and quartzitic schist. The limestone beds range from 100 to several hundred feet in the thickness, and the gypsum beds are 10 to 60 feet thick. The gypsum beds are lens-shaped and the material is usually white, crystalline, and compact. There is some associated anhydrite.

[20] Surr, Gordon, Gypsum deposits in the Maria Mountains of California: Min World, vol. 34, pp. 787-790, 1911.

[21] Hess, Frank L., op. cit., pp. 78-79, 1920.

[22] Tucker, W. B., and Sampson, R. J., op. cit., pp. 510-514, 1929.

This gypsum-bearing formation shows a general easterly trend, and variable dips, mostly to the north, which range from nearly flat to nearly vertical.

Occurrences in the Maria Mountains

Across the wash in the Maria Mountains, about 5 miles east of the area just described and several miles northeast of Cox, gypsum-bearing metasediments also occur. These are doubtless part of the Maria formation possibly connected under the wash with the area near Midland.

A large area of nearly 25 square miles of metasediments, regarded as part of the Maria formation, extends completely across the Maria Mountains as shown on the accompanying map (Pl. IV). The southeastern half of this area has been chosen as the type region of the formation because the metasediments are there typical; fossil remains occur in them, and gypsum beds are associated. The metasediments are thin- and thick-bedded quartzites and crystalline limestones together with smaller amounts of mica schist, crystalline gypsum, and a basal metaconglomerate. Steep, northerly to northeasterly dips are the general rule within this part of the Maria formation. No igneous rocks were seen cutting the metasediments though possibly there may be some. There are almost pure fine-grained quartzites and calcareous quartzites. There are fine-grained crystalline limestones, including arenaceous facies, and much nearly white crystalline fine-grained dolomitic limestone. Some phyllitic mica schists are interbedded. Much of the gypsum is medium-grained, nearly white, well-bedded, and shows thin, faint, dark bands paralleling the bedding. It contains considerable limy material. There is also some white fine-grained schistose selenite. Of particular interest is the basal conglomerate which is a conglomeratic sericite schist with small partly rounded pebbles. This conglomerate, 75 to 100 feet thick, rests by unconformity upon rather coarse-grained, pinkish gray granite of the Chuckwalla complex. This contact was definitely traced for more than a mile along the middle-southern border of this southeastern area of the Maria formation. A casual examination of this contact might not show the difference between the somewhat weathered granite and the conglomerate just above it. Evidently the material of the metaconglomerate was very locally derived from the granite. A few miles farther west of the locality just described, the Maria formation also rests upon the Chuckwalla complex, but faulting complicates the picture.

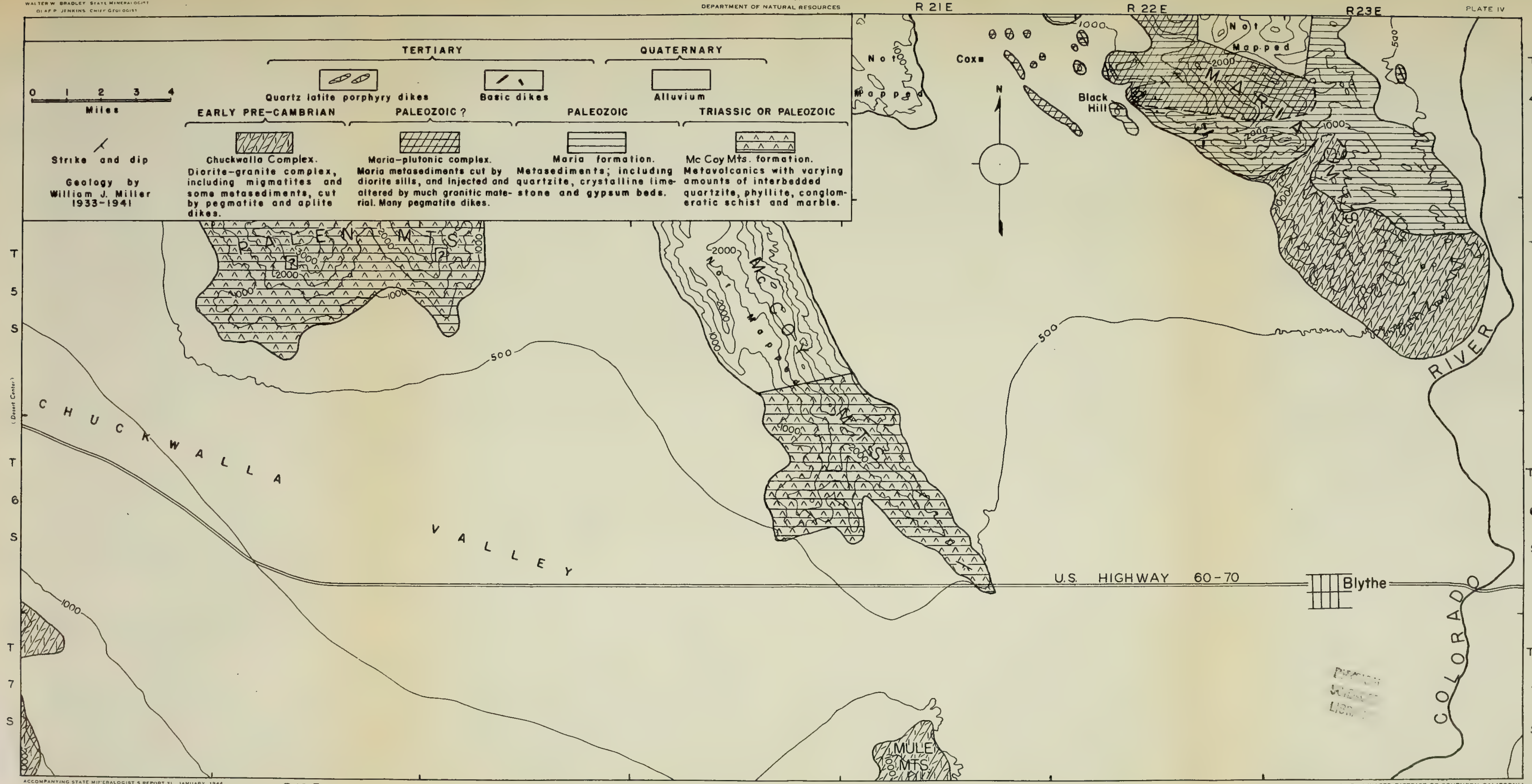
That part of the Maria formation which extends as a wide belt northward to the map border (Pl. IV) consists largely of metasediments like those just described, but the writer did not have opportunity to examine them carefully.

The western part of the Maria formation, which occupies about 6 square miles and extends from the midst of the mountains westward to their base, will be called the western area. It consists very largely of well-bedded, crystalline limestones and quartzites together with some mica schists. These are much like most of the metasediments of the already described southeastern area of the Maria formation, but with one important difference, namely, that the metasediments of the western area are cut by some diorite, granite, and pegmatite dikes and sills.

DIVISION OF MINES
WALTER W. BRADLEY STATE MINERALOGIST
OLAF P. JENKINS CHIEF GEOLOGIST

STATE OF CALIFORNIA
DEPARTMENT OF NATURAL RESOURCES

PLATE IV



ACCOMPANYING STATE MINERALOGIST'S REPORT XL JANUARY 1944

CONTOUR LINES FROM MAP BY THE METROPOLITAN WATER DISTRICT OF SOUTHERN CALIFORNIA

GEOLOGIC MAP OF THE BLYTHE AREA, CALIFORNIA

The thickness of the formation in this western area is probably not less than several thousand feet. Dips in the western area are moderately steep, and prevailingly to the north and northwest, but there are important local variations.

The southern half of the western area is characterized by a bold escarpment 1000 to 1500 feet high and 2½ miles long. Its steep front, facing south, is plainly visible from Blythe, 12 to 15 miles to the south. Maria beds, conspicuously exposed in the face of the escarpment, rest upon impure Chuckwalla granite and mixed rocks along and near the base of the escarpment. Toward the west, impure crystalline limestone lies on the granite, while, a mile farther east, glistening beds of muscovite-rich quartz schist, under the impure limestone, rest upon the granite. A mile still farther east, badly crushed quartzite rests upon the Chuckwalla. In the face of the escarpment the Maria beds strike northeast and dip 30°-40° NW. The contact between the Maria beds and the Chuckwalla shows similar strike and dip. Close to the contact, however, the Maria beds are nearly everywhere much disturbed and locally contorted. From bottom to top the beds consist of several hundred feet of quartzite, muscovitic quartz schist and impure crystalline limestone; a band of nearly white marble, about 200 feet thick, which extends diagonally (northeasterly) and conspicuously across the face of the escarpment; and hundreds of feet of well-bedded quartzite at the top. A few small scattering diorite, pegmatite, and silexite dikes cut the metasediments. Without doubt the Maria sediments were deposited upon the eroded surface of the Chuckwalla granitic rocks, but the fact that limestone, muscovite schist, and quartzite, marking different horizons of the Maria, rest upon the Chuckwalla within a short distance, coupled with the fact that both the basal schist and crystalline limestone are much sheared, and the brittle quartzite much brecciated, indicate that the original unconformity has been modified by faulting—probably by thrust faulting. East of this contact, and just across the mapped arm of the Chuckwalla complex, there is also evidence that the Maria-Chuckwalla contact has been modified by faulting.

The northern half of the western area of the Maria formation also shows many fine exposures consisting of alternating fine-grained well-bedded quartzites, and crystalline limestones, together with some mica schist and conglomeratic schist. Much of the limestone is dolomitic, but there is considerable moderately coarse-grained calcitic limestone. Dips are prevailingly steep (50°-70° N.). Diorite cuts these metasediments as sills, and many dikes cross-cut the bedding at various angles. Some of the sills are plainly visible from a distance of a mile or more. The diorite is dark gray, medium-grained, and usually massive, but with some locally foliated borders. Both metasediments and diorite are cut by many generally steep-dipping granite, aplitic granite, and pegmatite dikes (fig. 10). Some hematite iron ore has been produced by replacement of limestone near the western end of the area. Numerous pieces of the ore, derived from the outcrops, are scattered over the neighboring alluvial fan or wash east of Black Hill.

Four small areas of the Maria formation need brief mention. Black Hill consists of well-bedded quartzites and crystalline limestones which dip 50° SW., and are some 1200 to 1500 feet in thickness. A hill constituting the small area 1 mile north-northwest of Black Hill consists

mainly of alternating thin-bedded crystalline limestones and quartzites which dip steeply to the west-southwest (fig. 9). These beds are cut by some sills and dikes of diorite, gray granite, and pegmatite, usually less than a foot in width. Two hills, constituting two small areas 3 miles east-northeast and northeast of Cox, are largely well-bedded crystalline limestones and quartzites with some associated gypsum beds. They are cut by a little granitic material.

Age of the Formation

From the above statements it is evident that the Maria formation of the large area in the Maria Mountains is younger than the adjacent Chuckwalla complex, not only because of the great difference in the nature of the rocks, but also because an unconformity separates the formations. The writer has discovered crinoidal remains in the crystalline limestone associated with gypsum beds in the southeastern part of the large area of the Maria formation in the Maria Mountains. G. Arthur Cooper of the United States National Museum, Dr. Edwin Kirk of the United States Geological Survey, and Dr. Winifred Goldring of the New York State Museum, all of whom kindly examined the specimens, consider them to be of Paleozoic age, and possibly Silurian, but they have not attempted to make an accurate age determination of such fragmentary crinoidal remains. In any case, a post-Cambrian Paleozoic age of the Maria formation seems to be reasonably well established.

Comparisons With Other Regions

North of the mapped area (Pl. IV), and 28 to 32 miles north of Blythe, metasediments, with some associated gypsum beds, much like the Maria formation, occur extensively in the Riverside Mountains. In the eastern face of those mountains the metasediments rest unconformably upon impure foliated granite quite certainly belonging to the early pre-Cambrian Chuckwalla complex. The contact at one locality is faulted, both the metasediments and the fault dipping about 50° to the west, and the foliation dip of the granite being nearly vertical. No igneous rocks were seen cutting the metasediments. In many respects the Maria formation in the western area above described is similar to the metasedimentary series described by Harder [23] in the northern Eagle Mountains north of the Shaver Summit segment of the Palm Springs-Blythe strip. Both formations consist almost entirely of thick bodies of quartzites and crystalline limestones (mainly dolomitic); both are cut by diorite and quartz monzonite; both contain hematite ore as a limestone replacement product; and both rest (probably unconformably) upon an older igneous and metamorphic complex. The present writer tentatively regards this complex as early pre-Cambrian, and the overlying metasediments as Paleozoic.

Also according to Harder [24] a thick formation of metasediments, probably Paleozoic, including crystalline limestones, quartzites, slates, gypsum beds, and some iron ore, cut by much diorite and by some quartz porphyry, occurs in the northern part of the Palen Mountains. It is so much like the Maria formation that age equivalence is strongly suggested.

[23] Harder, Edmund C., op. cit., pp. 30-41, 1912.
[24] Harder, Edmund C., op. cit., pp. 410-411, 1910.

Maria-Plutonic Complex

General Statement

A large area of about 10 square miles has been mapped as Maria-plutonic complex in the Maria Mountains. How much farther north it extends was not determined. A number of much smaller areas of similar rocks are shown on the map (Pl. IV) east and southeast of Cox. Within these areas Maria metasediments were first cut by many sills and dikes of diorite after which both of these rocks, particularly the metasediments, were cut to pieces, injected, and digested by much granitic and pegmatitic granite material. The whole combination was then cut by numerous pegmatite dikes. Within these areas the Maria metasediments are usually scarcely recognizable as such.

Description of Areas

Several localities in the large area were examined in considerable detail in order to ascertain relationships. One of these is the steep, rocky hill about 500 feet high just across the narrow wash northeast of Black Hill. A large body of diorite forms the western flank of this rocky hill. Farther east on this hill steep-dipping Maria metasediments, including bedded quartzite, quartz schist, crystalline limestone, and muscovite schist, were cut first by some small sills of the diorite. Many sills and dikes of light-gray granite, pegmatitic granite, and pegmatite then cut the metasediment-diorite combination causing much granitization, and some injection lit-par-lit and digestion, particularly of the quartzites, quartz schist, and muscovite schist. The limestone beds were locally made tremolitic, but otherwise they were little affected by the intrusives as were also some muscovite schist and nearly pure quartzite beds. Apparently, however, thin-bedded quartzites and quartz-mica schists were usually soaked and injected lit-par-lit almost beyond recognition by the granitic material. Thin-banded injection gneisses and gray fine-grained feldspar-quartz-biotite schists are, therefore, common. There are some narrow bands of nearly pure diorite, pegmatitic granite, pegmatite, and silexite, but most bands of the gray medium-grained granite were contaminated with country-rock material, and in some cases contained muscovite and tiny garnets. The mixed rocks just described are not sharply separated from the adjacent Maria beds on the south side on the same hill. The boundary, for several miles eastward, between the Maria formation and the Maria-plutonic complex shows a similar general lack of sharpness. The recognizable metasediments of the complex are like those of the Maria formation; the Maria beds dip steeply and conformably under the mixed rocks; and the adjacent Maria beds are cut by some of the dioritic and granitic rocks, as already mentioned in the description of the western area of the Maria formation.

Another very instructive locality is the steep, rocky hill, about 500 feet high, situated between 3½ and 4½ miles due east of Cox. The western portion of this hill consists mainly of dark-gray diorite, varying to foliated metadiorite, cut to pieces, variably digested, and often injected lit-par-lit by strongly foliated, inpure granite. Much of the dark-gray mixture is crudely porphyritic. A large, irregular mass of purer, less foliated granite extends upward dikelike into the mixed rocks with contacts usually not sharp. This granite contains striplike inclusions of

diorite and granite-soaked diorite. Numerous pegmatite dikes, as offshoots of the granite, cut the whole combination of rocks, following the general foliation dip of about 45°, and forming an impressive display in the high, steep hillside. It is important to note that this strongly foliated igneous mixture dips conformably under the small body of Maria metasediments just to the west as shown on the geologic map (Pl. IV). The Maria beds are crystalline, interbedded, dolomitic limestones and quartzites in thin, straight beds with a steep dip to the west-southwest. They are cut by diorite, impure gray granite, and pegmatite, usually in the form of sills less than a foot in width. Some of the intrusives crosscut the bedding, usually at low angles. On the east side of the small area of Maria beds, the rocks just described merge into strongly foliated impure granite and diorite-granite mixed rocks, the latter including some variably banded gneiss. These rocks in turn merge into the diorite-granite mixed rocks of the western face of the 500-foot hill already described. It is clear, from these relationships, that both the dioritic and granitic rocks cut into, and are distinctly younger than, Maria beds. The mixed rocks of the western face of the 500-foot hill merge into a large mass of medium to moderately coarse-grained, nearly black diorite which constitutes the whole southwestern part of the hill. Foliated borders of this diorite are locally injected lit-par-lit by granite. The northeastern half of the hill is made up largely of light-gray fine-grained quartz-feldspar-mica schists, both biotitic and muscovitic, and generally rich in tiny grains of quartz. They are believed to represent well-bedded quartzites, quartz schists, and mica schists of the Maria formation which have been granitized and notably sheared. They dip steeply to the southwest.

Throughout the whole large area mapped as Maria-plutonic complex, there are more or less recognizable remnants of the metasedimentary rocks, particularly quartzitic and micaceous schists, cut by dikes and sills of dioritic rocks. Both are cut to pieces, injected parallel to the bedding (and foliation), and partly digested by granitic material. Most of the metasediments have, however, been granitized and otherwise altered almost entirely beyond recognition. Northwesterly strike and steep dips of foliation generally prevail, the dips being to the southwest in the middle-eastern part of the large area. Hundreds of large and small steep-dipping pegmatite dikes and sills, which cut the whole combination of rocks, are very conspicuous in the steep mountainsides. A great many large and small pieces of hematite ore are strewn over the broad wash at the mouth of the canyon between 4 and 5 miles a little north of east of Cox. This ore was produced by limestone replacement farther up the canyon.

Eight small areas of Maria-plutonic mixed rocks are shown on the accompanying map northeast, east, and southeast of Cox. These comprise mixed rocks much like those of the large area just described. Thus the small area $2\frac{1}{2}$ miles due east of Cox is a hill consisting of gray, fine-grained, quartz-mica-feldspar schists, some of which are muscovitic, but most of them biotitic. These schists quite certainly represent granitized well-bedded quartz schists and quartzites. They are cut by a little pegmatite. Similar rocks occur in the long, narrow area $1\frac{1}{2}$ to $3\frac{1}{2}$ miles southeast of Cox, but there are also some very thin-banded schists, crudely

banded gneisses, and porphyritic schists, all produced by granitization, injection, and digestion of biotitic and quartzitic schists by granite. Some bands of fine- to medium-grained diorite and crudely foliated light-gray granite also occur. A thin section of the rather pure, fine-grained equigranular, and allotriomorphic granite shows by percentages: quartz, 53; microcline, 40; biotite, $2\frac{1}{2}$; oligoclase, $3\frac{1}{2}$; and a little muscovite and zircon.

It seems clear, from the above descriptions, that the Maria-plutonic complex consists of Maria beds cut first by sills and dikes of diorite; then cut to pieces, granitized, injected lit-par-lit, and more or less digested by much granite; after which a great swarm of pegmatites cut the whole combination. We seem here to be dealing with the roof of a small batholith, or the cupola of a larger batholith, of granite whose penetrative and granitizing power was great because the magma was heavily charged with water and other volatiles as indicated by the great amounts of pegmatitic granite and pegmatite. A large part of the Maria formation, lying outside of the area of the complex, mostly or wholly escaped the attack.

Age of the Complex

Both the diorite and the granite are younger than the Paleozoic Maria beds, and so they may be late Paleozoic, or even as young as late Mesozoic, in age. The writer assigns them tentatively to the late Paleozoic for the following reasons which are strongly indicative, but by no means conclusive. The quartz monzonite and granodiorite of batholiths, presumed to be of late Mesozoic (late Jurassic?) age, in many parts of southern California are exceptionally massive; cut the country rocks sharply; and nowhere intimately penetrate, granitize, or inject the country rocks lit-par-lit on a large scale even where the country rocks could easily have been penetrated intimately. This is definitely true of important batholiths within 75 miles of the Maria Mountains, including the Coxcomb granodiorite and White Tank monzonite of the present report, and the granodiorite of the Needles region.[25] The same is true of the San Jacinto granodiorite of the Palm Springs region, as described in the present report, where distinctly older, (probably late Paleozoic) granitic material, rich in pegmatite and silexite, on a large scale intimately penetrated, granitized, and partly replaced Paleozoic or older metasediments, giving rise to the Palm Canyon complex. The Maria-plutonic complex is, in many ways, much like the Palm Canyon complex. In much the same way the metasediments of the Hinkley Valley complex in the Barstow region[26] have been intimately penetrated by silica-rich granitic material quite certainly much older than the massive (late Jurassic?) Victorville granodiorite not far to the south.

Metasediments With Iron Ore

A strip of metasediments with hematite ore lies 4 to $4\frac{1}{2}$ miles north-northwest of Eagle Mountain Camp. It is shown on the geologic map (Pl. III) as a nearly eastward-trending strip several hundred yards wide and more than a mile long. The highly metamorphosed strata consist largely of fine-grained quartzite with bedding fairly well preserved,

---

[25] Miller, William J., op. cit., pp. 120-121, 1944.

[26] Miller, William J., Geology of parts of the Barstow quadrangle, California: California Div. Mines Rept. 40, pp. 77-79, 1944.

together with some thin-bedded crystalline limestone and mica schist. Several narrow belts of the iron ore occur in the metasediments parallel with the bedding. Where the ore occurs, the limestone seems to be absent. The metasediments show dips of 50° to 70° N. They are cut by several narrow sills of granite and on the south side by a silexite sill several hundred feet wide. These sills are probably related genetically to the White Tank monzonite of late Mesozoic? age, a mapped body of which lies 2 to 3 miles south of the strip of metasediments. Several basic dikes of Tertiary age cut the combination of rocks.

The strip of rocks just described is bounded on both the north and the south by rocks belonging to the Chuckwalla complex. On the south side they are variably foliated and granulated, rather impure, locally porphyritic, granitic rocks. On the north side they are largely gray, porphyritic gneisses, with some large potash feldspars. The relation of the metasediments to these older rocks is not very clear, but considerable fault breccia in the metasediments parallel with the bedding indicates strongly that they have been downfaulted into the older rocks.

In regard to the origin of the ore beds, it seems clear that hot, ore-bearing solutions from the late Mesozoic ? intrusives deposited the hematite by replacement of limestone beds. This explains why limestone is absent where the hematite belts occur.

The strip of metasediments and iron ore just described is the easternmost extension of a much larger body of similar rocks described by Harder [27] as occurring in the Eagle Mountains. Harder describes a thick series of metasediments, including strongly metamorphosed quartzites, crystalline limestones (dolomitic and calcitic) and conglomerate, in which limestone beds have been extensively replaced by hematite ore. He seems to be quite sure (p. 27) that these metasediments rest unconformably upon a complex of granite-gneiss, augen gneiss, schist, and some very highly altered metasediments. He also says that large sills of quartz monzonite cut the metasediments, and that irregular dikes of aplite, diorite, and andesite porphyry cut the whole combination. Harder gives no age assignments, but the present writer suggests early pre-Cambrian for the oldest metamorphics; Paleozoic (or possibly late pre-Cambrian) for the metasediments with iron ore; and late Mesozoic for the quartz monzonite. In most respects the ore-bearing metasediments are like those of the Maria formation already described.

TRIASSIC OR LATE PALEOZOIC ROCKS

McCoy Mountains Formation

General Statement

The McCoy Mountains formation is here so named because of its typical occurrence in the southern part of the McCoy Mountains which seems to be made up entirely of the formation. It is very different from any other formation within the Palm Springs-Blythe strip. It consists very largely of metavolcanics with some interbedded metasediments. The metavolcanics are mainly or wholly metamorphosed, variably foliated, well-bedded tuffs, with possibly some thin, interbedded, altered, acidic lava flows. The metasediments include conglomerate, quartzite, crystalline limestone, and phyllitic schists.

[27] Harder, Edmund C., op. cit., pp. 22-27, 30-41, 1912.

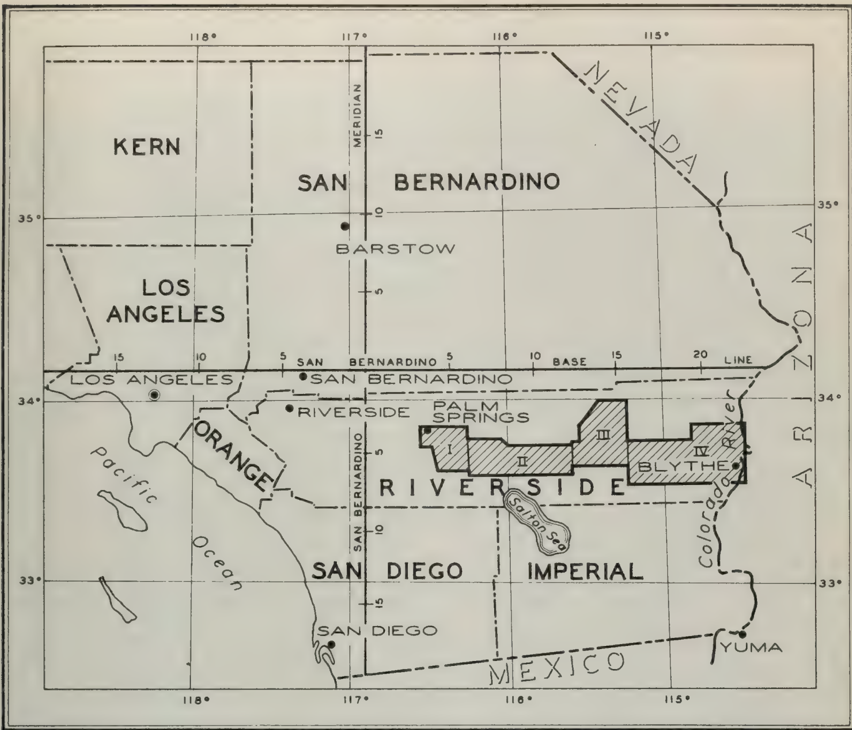


FIG. 1. Index map showing position of geologic maps (Plates I, II, III, IV) which comprise a strip of territory extending from Palm Springs to Blythe, Riverside County, California.

FIG. 2. A detail view of the Chuckwalla complex. Nearly white granite contains crudely parallel xenoliths of metadiorite, some of which have been injected lit-par-lit. In Mecca Hills, 3 miles west of Shaver Well.

FIG. 3. A detail view of the Chuckwalla complex. Dark-gray diorite and metadiorite cut to pieces, somewhat granitized, and locally injected lit-par-lit by light-gray granite. Some of the diorite is schistose, and the crudely foliated granite is contaminated with dioritic material. The crudely foliated mass near the center is a granite-diorite syntectic. East Eagle tunnel portal, 3 miles southwest of Eagle Mountain Camp.

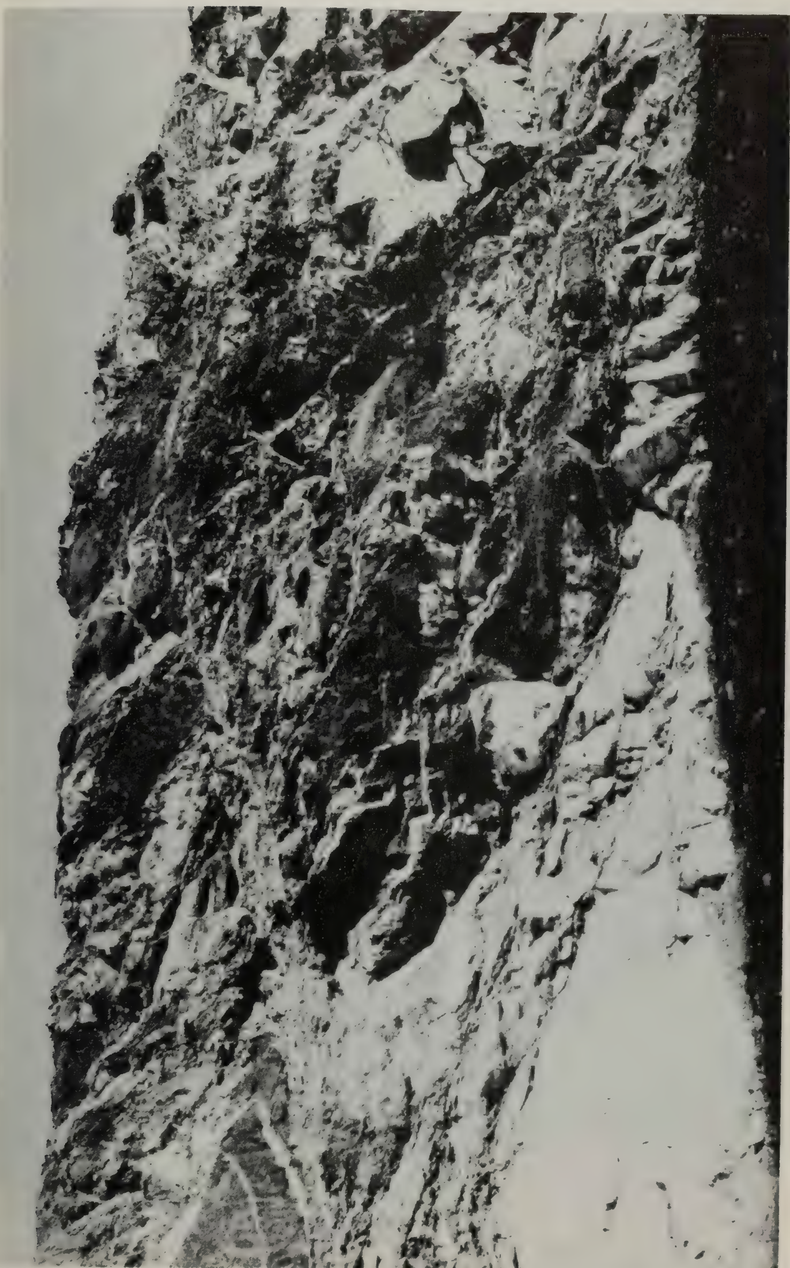


FIG. 4. An exposure of the Chuckwalla (?) complex showing hornblende-rich diorite cut to pieces and injected locally with pink granite and pegmatitic granite. Seven-level Hill, 6 miles southwest of La Quinta.

FIG. 5. Steep-dipping Palm Canyon metasediments, including some crystalline limestone beds, injected lit-par-lit by granite. There are some thin sills of foliated diorite. By the highway $6\frac{1}{2}$ miles northwest of Palm Springs.

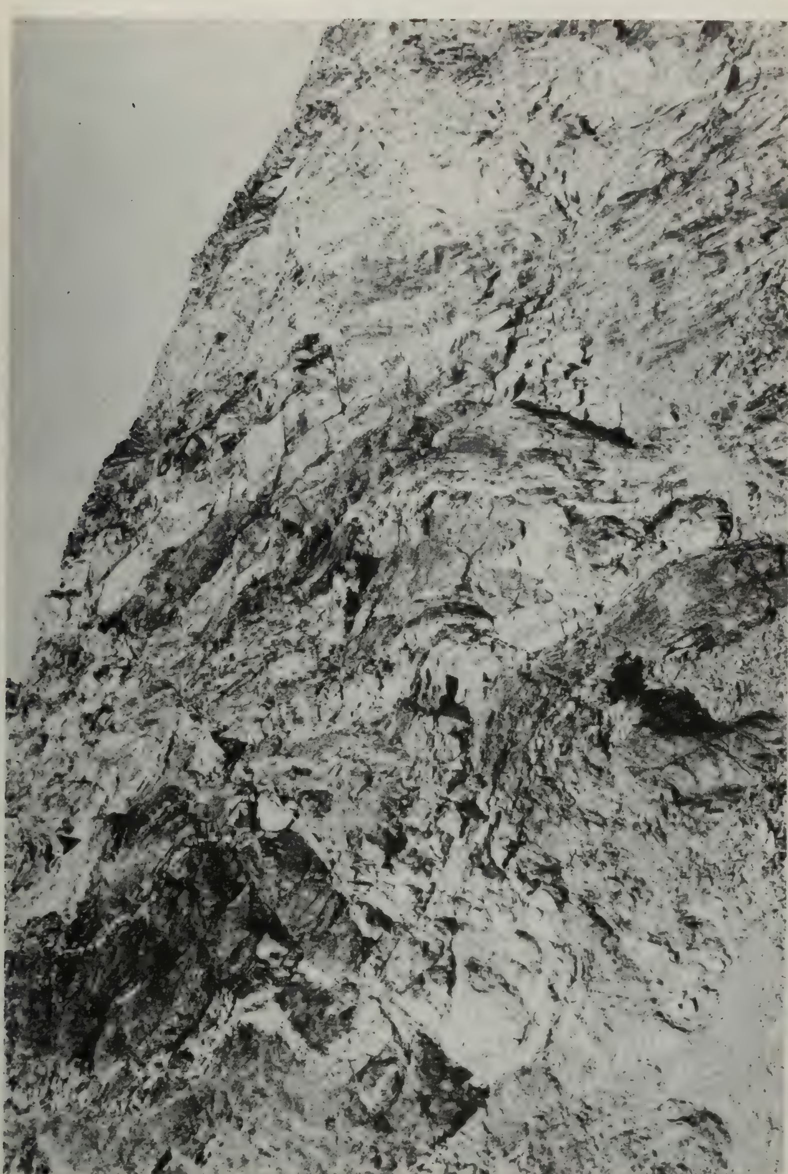


FIG. 6. Palm Canyon metasediments, including crystalline limestone, quartzite, and mica schist, cut by diorite (varying to metadiorite), and injected lit-par-lit by granitic material. The whole combination is much deformed. By the highway $4\frac{1}{2}$ miles west-southwest of Indian Well in the Palm Springs-Indio map area.

FIG. 7. Palm Canyon metasediments injected lit-par-lit by granitic material. In Dead Indian Canyon a third of a mile west of the highway, 6 miles west-southwest of La Quinta.

FIG. 8. Thin-bedded Palm Canyon metasediments cut by a few small sills of diorite; both rocks injected lit-par-lit and largely replaced by pegmatitic granite and silexitic material. Dead Indian Canyon a quarter of a mile west of the highway, 6 miles west-southwest of La Quinta.

FIG. 9. Well-bedded dolomitic marble and quartzite of the Maria formation. In the small area 3½ miles east of Cox.

FIG. 10. Dark-gray quartzitic schist of the Maria formation cut by pegmatitic dikes. About 1 mile east of Black Hill in the Maria Mountains.

FIG. 11. Steep-dipping beds of the McCoy Mountains formation consisting largely of quartzite, mica schist, and crystalline limestone. East base of the Coxcomb Mountains near the northern boundary of the Desert Center map area.

FIG. 12. Steep-dipping beds of the McCoy Mountains formation consisting largely of metavolcanics with some interbedded quartzite, phyllitic quartzite, and metaconglomerate. Southwestern front of the McCoy Mountains 15 miles a little north of west of Blythe.

FIG. 13. Conglomeratic schist in the McCoy Mountains formation near the southeastern end of the McCoy Mountains and three-quarters of a mile north of the highway.

FIG. 14. Muscovitic schist of the McCoy Mountains formation, with nearly vertical dip, near the western end of the contact between the Coxcomb granodiorite and the McCoy Mountains formation in the Coxcomb Mountains.

FIG. 15. The contact between the McCoy Mountains formation (darker portion) and the Coxcomb granodiorite (lighter portion) in the Coxcomb Mountains.

FIG. 16. A detail view of crudely foliated Bradley granodiorite with hornblende-rich segregation masses or inclusions. Just west of the highway in Dead Indian Canyon, 6 miles west-southwest of La Quinta.

FIG. 17. A detail view of highly foliated Bradley granodiorite. Near the mouth of Andreas Canyon 3½ miles south of Palm Springs.

FIG. 18. A general view of slightly foliated Bradley granodiorite $1\frac{1}{2}$ miles southeast of Indian Well west of Indio.

FIG. 19. A sill-like body of San Jacinto granodiorite sharply cross-cutting folded Palm Canyon metasediments which were somewhat injected lit-par-lit by older granitic material. In Dead Indian Canyon ½ mile west of the highway 6 miles west-southwest of La Quinta.

FIG. 20. Three dikes of San Jacinto granodiorite sharply cross-cutting folded Palm Canyon metasediments which were injected lit-par-lit by older granitic material. In Dead Indian Canyon ½ mile west of the highway 6 miles west-southwest of La Quinta.

FIG. 21. The northern part of the long quartz latite porphyry dike which extends southwestward from Desert Center.

Fig. 22. Nearly horizontal non-marine red sandstone beds of late Tertiary age in Painted Canyon in Mecca Hills 4 miles west of Shaver Well.

Fig. 23. Late Tertiary non-marine sandstones resting unconformably upon steep-dipping banded gneiss of the early pre-Cambrian Chuckwalla complex.

Description of Areas

The following descriptions, based upon numerous representative rock specimens and field notes, will give a good idea of the nature of the formation in the southern part of the McCoy Mountains. Most of the rocks are metamorphosed, well-bedded (usually thin-bedded), fine-grained, metatuffs. Most of them are light greenish gray, but some are light gray to light brownish gray. A given bed is very uniform in composition and texture, but variations in color, texture, and composition may show in a hand specimen, giving the rock a banded appearance which is in reality bedding preserved after recrystallization of the tuff beds. There is also a good deal of ashen gray, fine-grained, phyllitic and sericitic schist derived from tuff. A little quartzitic, phyllitic, and limy metasedimentary material is interbedded with the metavolcanics in some places. Nearly all specimens show poorly to highly developed foliation and shearing parallel with the bedding so that they are usually metatuff schists. The very fine-grained, phyllitic specimens may be taken for either metavolcanics or metasediments, but nearly always they are the former. Of particular interest is the conglomeratic schist (fig. 13). Many well-rounded to subrounded pebbles and cobblestones, as much as 10 inches in length, lie in a bluish gray schistose arkosic matrix. Most of the pebbles are quartzite, but some are aplitic and granitic. They are little, if at all, flattened parallel with the foliation and bedding. Near the southeastern tip of the mountains, this conglomeratic schist forms a stratigraphic unit several hundred feet thick. A similar rock was observed in the southwestern lobe of the mountains where some quartzite and crystalline limestone also occur (fig. 12). Southwesterly dips of 30° to 50° prevail in the southwestern part of the McCoy Mountains, suggesting a thickness of many thousands of feet for the formation.

A thin section of the commonly occurring fine-grained, greenish gray, well-bedded, foliated metatuff from the southeastern tip of the McCoy Mountains shows numerous irregular grains of quartz and oligoclase together with a good many small irregular grains of epidote and magnetite. These minerals lie in a very fine-grained, generally indeterminate groundmass comprising about 60 percent of the section. The longer axes of the mineral grains are parallel with bedding and foliation. Tiny veinlets of quartz cross-cut the section. Another thin section from the same locality is similar, but it contains about 40 percent of determinable quartz, numerous tiny flakes of sericite, and very little determinable feldspar in the exceedingly fine-grained groundmass.

A thin section of the abundant fine-grained, greenish gray metatuff from the southwestern lobe of the McCoy Mountains shows by volume percentages: quartz in angular to subangular grains, 25; oligoclase, 15; biotite, 15; magnetite, $3\frac{1}{2}$; some scattering grains of titanite, zircon, epidote, and calcite; numerous tiny sericite flakes; and a very fine-grained, indeterminate groundmass, 40. Crude foliation and bedding are parallel.

The whole southern part of the Coxcomb Mountains, comprising an area of about 15 square miles, consists of the McCoy Mountains formation. Metavolcanics predominate greatly, but metasediments are much more commonly associated than they are in the McCoy Mountains. Metasediments occur in various parts of the area, being particularly

common in the northeastern part. These include thin-bedded, gray to greenish gray, fine-grained quartzites, thin beds of fine-grained, crystalline limestones, conglomeratic schists, arenaceous phyllites, and quartz-mica schists. There are also sericitic schists which may or may not be metasediments.

The metavolcanics include much fine-grained, greenish gray, foliated metatuff like that so common in the McCoy Mountains. In addition to these, gray, dark gray, red, and purple fine- to medium-grained metatuffs are common. Some of the gray rocks could easily be mistaken for acidic lava-flows in the field, but several thin sections prove them to be metatuffs.

No attempt was made to work out structural details throughout the area, but, in a general way, northeasterly to northerly dips of 30° to 40° seem to prevail. Even if we allow for considerable folding within the area, the formation must be at least some thousands of feet thick. Bedding and foliation in both the metavolcanics and metasediments are parallel. A few small granite and pegmatitic granite dikes cut the formation.

Very brief mention of this metasedimentary-metavolcanic formation of the southern Coxcomb Mountains has been made by Hazzard, Gardner, and Mason [28] who say:

> "In the southern portion of the Coxcomb Mountains, north of Desert Center, folded conglomerates, sandstones, shales, limestones, acid flows, and tuffs are intruded by Jurassic (?) quartz monzonite; though altered to schists at the contact, the degree of metamorphism lessens rapidly southward."

According to the observations of the present writer, however, all of the sediments are notably and rather uniformly metamorphosed excepting on the north near the contact with the Coxcomb granodiorite where metamorphism is distinctly greater as will be described. Also, acidic lava-flows may be present.

Four thin sections of the gray, greenish gray, and purplish gray, fine-grained metavolcanics from the southern and southwestern parts of the large area of the McCoy Mountains formation in the Coxcomb Mountains show the following constituents by volume percentages: orthoclase, 15-40; oligoclase-andesine, 8-40; quartz, 3-20; sericite, 2-10; magnetite, 0-3; calcite, 0-5; epidote, 0-3; a few grains of zircon and apatite in one section; and indeterminate very fine-grained groundmass, 30-45. All are holocrystalline and inequigranular with maximum grain size about 2 millimeters. The feldspars are usually much decomposed. Probably all four are metamorphosed tuffs, but possibly one or two represent altered acidic lava flows. All sections are from variably foliated specimens.

A thin section of the red metatuff has a composition much like the four sections just described, but with some mineral grains several millimeters in length, and with several percent of piedmontite in the form of tiny prisms with a yellow-red-pink pleochroism. The piedmontite gives the rock its red color.

Some features of particular interest were observed along the contact between the large area of the McCoy Mountains formation just described and the Coxcomb granodiorite. The generally sharp contact, 2½ miles long, is very clearly exposed across the range (fig. 15). A

[28] Hazzard, John C., Gardner, Dion L., and Mason, John F., op. cit., p. 279, 1938.

tunnel of the Colorado River Aqueduct cuts through the contact. Along the western part of the contact the McCoy Mountains formation, including metasedimentary phyllitic schist and crystalline limestone, and metavolcanics, dips 70°-80° SW., away from the granodiorite. Close to the contact the degree of metamorphism of the McCoy Mountains beds is distinctly greater than it is 200-300 yards away, there being several zones in order including highly metamorphosed dioritic gneiss and biotite-hornblende schist, less crystallized biotite-hornblende schist, sericite schist (fig. 14), and finally the typical moderately metamorphosed McCoy Mountains beds little if any affected by the contact action. A number of offshoots of the granodiorite, mostly in the form of sills 1 to 30 feet wide, lie in the contact zone within 100 yards of the contact. These no doubt facilitated the metamorphism of the McCoy Mountains beds. Foliation and bedding always coincide. There are a few crude suggestions of lit-par-lit structure. Within the granodiorite, near the contact, there are several highly metamorphosed schist xenoliths, shown as one on the accompanying map (Pl. III).

From the eastern end of the contact westward for a little more than a mile, the granodiorite lies in sharp contact against metasediments which are dark gray quartzites and various schists including conglomeratic schists. The metasediments dip very steeply southeastward and away from the contact. Some small dikes of granodiorite (finer-grained facies), aplitic granite, pegmatite, and silexite cut right across the structure of the metasediments. Some aplite and aplitic granite dikes, and also a few small xenoliths of the metasediments, occur in the granodiorite. At one place a large dike offshoot of the granodiorite cuts diagonally across the bedding of the metasediments for hundreds of feet. It contains several inclusions of metasediments with variable strikes and dips, but most of them are roughly parallel to the dike walls. One of these inclusions, 40 feet long, is a conglomeratic schist with many well-rounded pebbles. A quarter of a mile west of the dike a large body of the conglomeratic schist contains pebbles highly flattened parallel with the foliation. Along the whole eastern part of the contact between the granodiorite and McCoy Mountains beds, the latter are not at all injected lit-par-lit.

Two areas of the McCoy Mountains formation flank the large area of Coxcomb granodiorite—one on the east and the other on the west—near the northern border of the map (Pl. III). The eastern area comprises fine-grained quartzites, crystalline limestones, and schists (partly or wholly metavolcanic) (fig. 11). A dip of 50° SW., toward the granodiorite, suggests downfaulting of the tilted metasediments against the batholith. The western area contains similar rocks which dip 50° W.

On the accompanying geologic map (Pl. III), the southern part of the Palen Mountains are represented as McCoy Mountains ? formation. This area is very difficult to reach and study. Very limited observations by the writer indicate that the rocks are largely or wholly similar to those of the McCoy Mountains formation, but there should be more field work upon which to base a conclusion.

Age of the Formation

The age of the McCoy Mountains formation is indicated on the accompanying geologic maps as Triassic or Paleozoic. Hazzard, Gard-

ner, and Mason [29] have very briefly mentioned metamorphosed volcanic-sedimentary series in three areas—one in Ord Mountain southeast of Daggett, another in Old Dad Mountain southeast of Baker, and a third in the southern Coxcomb Mountains, where the writer's McCoy Mountains formation is located. These writers suggest an early Mesozoic age for these rocks, stating that they are far less metamorphosed than the early pre-Cambrian complex; that they are unlike known late pre-Cambrian rocks in the desert region; that Paleozoic volcanics are unknown in the region; and that the rocks are intruded by late Jurassic (?) plutonics. They suggest a correlation with early Mesozoic metavolcanics and sediments in the Inyo and Santa Ana Mountains. But the present writer has found metavolcanics (largely metatuffs) associated with late Paleozoic (probably Mississippian) quartzites and crystalline limestones north and northeast of Victorville, in one place only 15 or 20 miles west of the Ord Mountain locality. This volcanic-sedimentary series is probably a little more metamorphosed than the McCoy Mountains formation, which is more metamorphosed than the Triassic volcanic-sedimentary series in the Santa Ana Mountains; so the degree of metamorphism is not too good a criterion by which to judge the age. Furthermore, Hazzard [30] earlier described Lower Triassic marine strata occurring in the Providence Mountains only 20 or 25 miles east-southeast of his above-mentioned metamorphosed volcanic-sedimentary series in Old Dad Mountain. Significantly, these definitely known Triassic strata, as described by Hazzard, are not metamorphosed, and they do not contain volcanic rocks.

The writer searched in vain for fossils in the McCoy Mountains formation, but, on the basis of the available evidence, a late Paleozoic or Triassic age of the formation seems reasonably certain, with the probability favoring the Paleozoic age.

LATE JURASSIC OR OLDER ROCKS

Bradley Granodiorite

General Statement

The Bradley granodiorite is here so named because of good exposures of the typical rock in lower Bradley Canyon southeast of Cathedral City. It all occurs within the Palm Springs-Indio portion (Pl. I) of the Palm Springs-Blythe strip. It varies considerably in composition, from quartz diorite to quartz monzonite. There is also a wide range in texture and structure, from much granulated, sheared, and strongly foliated to granitoid and little foliated. Where fresh, the rock varies from light gray to dark gray, and it weathers to brown or dark brown, causing the large outcropping masses, covered with little vegetation, to present a somber appearance. In a good many places the rock is crudely banded because of differential shearing or injection of some thin bands or sills of light-colored granitic rocks. Fraser [31] calls the Bradley granodiorite in the vicinity of Palm Springs "granite-gneiss," but this is a misnomer because none of it has the composition of true granite. As already pointed out, some small unmapped sills of the Bradley granodiorite cut the Palm Canyon complex; and the Bradley granodiorite is cut by some small sills and dikes genetically related to the San Jacinto batholith.

---

[29] Hazzard, John C., Gardner, Dion L., and Mason, John F., op. cit., p. 279, 1938.
[30] Hazzard, John C., Lower Triassic rocks in San Bernardino County, California: Geol. Soc. America, Proc. 1936, p. 329, 1937.
[31] Fraser, Donald M., op. cit., pp. 509, 530-531, 1931.

Petrographic Descriptions

Megascopically, six representative specimens from the type area southeast of the mouth of Bradley Canyon are all distinctly but crudely foliated. Five of them are rather massive in general appearance, medium- to moderately coarse-grained, somewhat inequigranular, and medium gray in color. They contain about 20 percent of biotite and hornblende, the latter often as subhedral to euhedral crystals as much as one centimeter in length, and a few scattering subhedral to anhedral potash feldspars of similar size. The sixth specimen is darker gray and more foliated and sheared. A thin section of the gray, more massive rock shows by volume percentages: oligoclase-andesine, 48; orthoclase, 12; quartz, 15; hornblende, 13; biotite, 8; epidote, $2\frac{1}{4}$; titanite, $\frac{3}{4}$; apatite, $\frac{1}{4}$; and still smaller amounts of magnetite, zircon, allanite, and sericite. The section is holocrystalline, mostly medium-grained hypidiomorphic inequigranular, crudely foliated, somewhat sheared, and considerably granulated, with most of the crushed material irregularly distributed between the uncrushed mineral grains. There are some crude mortar and suture textures. The hand specimen is cut parallel with the foliation by a pegmatitic granite dike.

A representative specimen from the area between Bradley and Cathedral Canyons is much like the type rock just described, but it contains more quartz and orthoclase, and less plagioclase and hornblende. In thin section it is also more foliated, sheared, and granulated. The section shows some biotite flakes in relatively large clusters, but most of it occurs as tiny flakes mixed with more or less finely crushed quartz in narrow and wide belts between large feldspar grains. Some feldspar fragments have been rotated with swirls of granulated biotite and quartz around them. The hand specimen shows a crude suggestion of banding probably caused by shearing of crushed feldspar phenocrysts into rough lenslike masses.

A representative specimen from the Ramona Creek area $2\frac{1}{2}$ miles south of the mouth of Magnesia Spring Canyon, looks much like the Bradley Canyon type rock, and it is mineralogically similar, but with more biotite and less hornblende. Texturally, however, it is notably different, being medium-grained, granitoid, nearly equigranular, hypiodmorphic, and crudely foliated or gneissoid. Both feldspar and hornblende range from anhedral to euhedral. There is little granulation, shearing, or other evidence of metamorphism. This specimen is a little-altered granodiorite. It is cut parallel with the foliation by a granite dike half an inch wide.

Several specimens from the general vicinity of La Quinta have been studied. One of these from fine exposures in the road-cut 2 miles north-northeast of La Quinta is largely light gray, medium-grained, granitoid, and slightly foliated (gneissoid) with scattering anhedral to subhedral hornblendes and feldspars, from $\frac{1}{2}$ to 1 centimeter in length, often arranged roughly parallel with the foliation. A microscopic section shows the following minerals by volume percentages: oligoclase-andesine, 35; othoclase, 26; quartz, 20; microcline, 7; biotite, 8; hornblende, $2\frac{1}{2}$; magnetite (mostly in tiny cracks), $\frac{1}{2}$; myrmekite, $\frac{1}{2}$; epidote, $\frac{1}{4}$; and still less apatite and zircon. The granitoid texture is somewhat modified by local granulation. This rock is a very little-altered quartz monzonite. A specimen from 1 mile northeast of La Quinta is much the same, but it

has more microcline, less orthoclase, 1½ percent of titanite, and it shows considerable granulation, especially of the quartz. This is a still more modified quartz monzonite. Another specimen, collected 2 miles southeast of La Quinta, is a medium gray, medium-grained, largely granitoid, slightly gneissoid granodiorite (fig. 18). A thin section shows: oligoclase-andesine, 45; microcline, 15; orthoclase, 5; quartz, 15; biotite, 12; hornblende, 4; myrmekite, 2; titanite, ¾; epidote, ¾; apatite, ½; and a little zircon. There is some local granulation and other evidence of alteration. Still another specimen, from 4 miles southwest of La Quinta, is an allotriomorphic, granitoid, slightly gneissoid, very little modified granodiorite containing microperthite instead of orthoclase. There are some small, scattered feldspar phenocrysts.

The following descriptions of the Bradley granodiorite in the general vicinity of Cathedral City and Palm Springs are based upon field notes and 16 representative specimens. Megascopically these rocks are gray to dark gray, with 20 to 35 percent of mafic minerals, and crudely to highly foliated. Very commonly they appear medium-grained with scattering anhedral to subhedral white feldspars 5 to 8 millimeters in length, most of them with long axes paralled with the foliation. In some cases there are subhedral hornblendes 5 to 8 millimeters in length. Local facies are almost fine-grained, as from the lower end of Tahquitz Canyon. Nearly all specimens appear to have been subjected to shearing. In the field the rocks would be called dioritic gneiss. In a few places basic schlieren or indefinite inclusions were observed. Locally there may be very crude suggestions of banding probably resulting from crushing and shearing of feldspar phenocrysts into crude lenses.

In thin section a specimen from three-fourths of a mile west-northwest of Cathedral City shows by percentages: oligoclase-andesine, 60; quartz, 15; biotite, 15; hornblende, 8; magnetite, 1; and less than 1 percent each of calcite, titanite, apatite, allanite, and zircon. There is very little if any orthoclase, and so the rock is a quartz dioritic gneiss. It is inequigranular with augen of plagioclase as much as 5 millimeters in length. Considerable sheared, sliced, and crushed material, including all important minerals, curves around the augen. Both feldspars and biotites are often bent. A similar specimen from the same general vicinity (1¼ miles west of Cathedral City) contains more quartz and hornblende, and less plagioclase. There is considerable granulation of all important minerals and some crude mortar texture, but there are no augen. Also there are a few small grains of monoclinic pyroxene and hypersthene. This rock is also a quartz dioritic gneiss.

A specimen of the dark gray, strongly foliated, somewhat porphyritic, inequigranular rock was collected 3 miles west-northwest of Cathedral City. In thin section it shows the following minerals by volume percentages: oligoclase-andesine, 40; orthoclase, 15; quartz, 22; hornblende, 9; biotite, 9; epidote, 3; magnetite, 1; titanite, ½; apatite, ¼; and zircon, ¼. All of the important minerals, especially the quartz, have been sheared and granulated, often to very fine-grained fragments, leaving many small and large more or less corroded cores of the feldspar and quartz. The epidote occurs both as irregular, scattered grains, and as crack fillings. This rock is clearly a strongly foliated, much-altered granodiorite.

A specimen taken from just west of the business section of Palm Springs represents a common facies of the Bradley granodiorite so prominently exposed for 10 miles along the eastern base of San Jacinto Mountain. It is dark gray, highly foliated, medium- to fine-grained, and inequigranular, with irregularly distributed white, anhedral plagioclases often 3 to 7 millimeters in length. A thin section shows: oligoclase-andesine, 40; quartz, 30; biotite, 16; hornblende, 13; and less than 1 percent each of titanite, allanite, apatite, and zircon. All of the common minerals are irregularly granulated, leaving many large and small uncrushed portions of feldspar. The section shows much shearing and a flaser texture with suggestions of a micro-augen texture. The rock is a much altered quartz diorite.

A specimen from near the highway 4 miles northwest of Palm Springs is a granodiorite-gneiss with biotite, but without hornblende. It is gray, medium- to fine-grained, and well foliated. Under the microscope the rock shows much granulation, often in very small grains, and some crude mortar texture. A similar facies was collected from the lower end of Tahquitz Canyon near Palm Springs. Locally within the long, wide belt of generally highly foliated Bradley granodiorite or quartz diorite along the eastern base of San Jacinto Mountains, as on the mountain spur just west of Palm Springs, there are zones of little-foliated quartz diorite without sharp borders.

Origin of Differences in Composition, Structure, and Texture

Fraser [32] says that his granite-gneiss (the present writer's Bradley granodiorite) along the base of San Jacinto Mountain always contains orthoclase, but no hornblende. The writer, however, has found facies without orthoclase, and others with hornblende and small amounts of titanite, allanite, and zircon, in addition to the minerals listed by Fraser (p. 531). Certain facies in the vicinity of La Quinta contain potash feldspars (microcline and orthoclase) in equal amounts with oligoclase-andesine. Accordingly the rock varies much more than indicated by Fraser, that is, from quartz diorite through granodiorite to quartz monzonite; and nearly all of these facies contain considerable amounts of both biotite and hornblende. But the rock never has the composition of a true granite. Its average composition is about that of a granodiorite. The variations in composition are doubtless results of magmatic differentiation.

Fraser [33] properly emphasizes both the characteristic crushing or granulation of all important minerals and the foliation of the rock, pointing out that both features, though usually developed conspicuously, vary greatly in degree. He argues, from both the nature of the crushed minerals and the mode of occurrence of myrmekite, that

> "Final consolidation of the rock [magma] must have followed most of the fracturing [and crushing]; that is, it followed the development of the gneissic structure."

In other words both foliation and granulation were produced largely or wholly during late stages of magma consolidation, the former being a primary flow-structure, and the latter protoclastic granulation. The present writer believes that this is the correct explanation of most of the

[32] Fraser, Donald M., op. cit., pp. 530-531, 1931.
[33] Fraser, Donald M., op. cit., p. 531-533.

granulation and foliation. In view of the fact, however, that, in so many of the specimens and thin sections examined, there is much evidence of shearing and of granulation of quartz, which was the last mineral to crystallize, post-consolidation dynamic action seems to have produced at least some additional granulation and shearing to accentuate the foliation. Such dynamo-metamorphism could have accompanied intrusion of the still later San Jacinto granodiorite. But the writer confesses his inability to evaluate such possible shearing and cataclastic granulation.

Why are the foliation and granulation so much more highly developed in some parts of the Bradley granodiorite than in others? Generally speaking, the more highly foliated rocks are most granulated. Also it seems clear that these features are most strongly developed where the rock cuts the Palm Canyon metasediments, usually in the form of sills, or as large and small dikes approaching sills in structure. The well-bedded Palm Canyon metasediments, with their abundant limestone, are relatively weak and easily deformed. It is suggested that, in such an environment, the stress applied during the intrusion of the sill-magma would readily produce differential magmatic movements resulting in primary foliation, shearing, and granulation during late stages in the consolidation of the magma. Conditions would then still be favorable for some post-consolidation shearing and granulation. More massive, less granulated, facies of the Bradley granodiorite usually occur where bodies of it are not closely associated with the metasediments, and where they have invaded the resistant Chuckwalla complex of Seven-level Hill. This is well illustrated by the granodiorite of the southeastern part of the Palm Springs-Indio map area (Pl. I). The four areas, including Indio Mountain ridge, are no doubt connected under the two washes, thus constituting a single, large body of the granodiorite.

The highly foliated, sheared, and granulated Bradley granodiorite, just west of Palm Springs and south for some miles, lies against the San Jacinto granodiorite. No doubt the Bradley granodiorite there cut sill-like into the Palm Canyon complex, as it did farther south in Palm Canyon, and that the metasediments were then cut out locally by the San Jacinto batholith whose influence still further increased shearing and granulation of the adjacent Bradley granodiorite.

Relations to Other Formations

The Bradley granodiorite is very definitely younger than the Chuckwalla complex of Seven-level Hill, as shown by sharply defined intrusive contacts of the former against the latter. Such contacts are well shown at several places in road cuts on Seven-level Hill east of Carrizo Canyon.

Evidence is also conclusive that the granodiorite is younger than the Palm Canyon complex, including both its metasediments and closely associated igneous rocks. A few of many places where small and large inclusions of the Palm Canyon complex were observed in the granodiorite are: 2 miles southwest and 1 to 2 miles west, of Cathedral City; the mountain spur just west of Palm Springs; and 3 and 5 miles south of Palm Springs. The last two named are large enough to show on the geologic map. In nearly all cases these inclusions are granitized, silexitized, or lit-par-lit injected metasediments with associated crystalline limestone.

Between Bradley Canyon and Magnesia Spring Canyon there is a perfectly exposed igneous contact between the typical Bradley granodi-

orite-gneiss and typical Palm Canyon metasediments including crystalline limestone, and granitized and lit-par-lit injected metasediments. The contact is sharp and steep. A lenslike inclusion of the Palm Canyon, 200 feet long and 30 feet wide, lies in the granodiorite close to the contact, and a dike of the granodiorite cuts sharply into the Palm Canyon for 50 feet. In a general way the metasediments dip steeply under the granodiorite, the foliation of both being roughly parallel. The metasediments are, however, contorted irregularly within a few hundred feet of the contact, so that very locally foliation dips of adjacent granodiorite and metasediments may be very different.

Fraser has mapped a steep-dipping sill of the Bradley granodiorite-gneiss in the granite and silexite-injected Palm Canyon metasediments for 10 or 12 miles through Palm Canyon. On the accompanying map (Pl. I) the 2½-mile-long body of granodiorite-gneiss, between Magnesia Spring Canyon and Dead Indian Canyon, shows a general sill-like relation to the Palm Canyon complex. Various sills, too small to be mapped, also occur within the Palm Canyon complex, a good case in point being in the narrows of Cathedral Canyon 2 miles southwest of Cathedral City.

The age relation between the Bradley granodiorite and the San Jacinto granodiorite is not so clear, but the writer believes that the Bradley is at least somewhat older, and possibly much older. Fraser [34] maintains that his granite-gneiss (Bradley granodiorite) represents an eastern marginal phase of his San Jacinto granite batholith, in which a gneissic structure developed as a result of cataclastic and protoclastic processes. He says (p. 531) that, in the field, there is a gradation of granite-gneiss into the granite of the batholith, and that

> "In thin sections, the gradation is more interesting. As the granite is approached, the gneiss changes by decrease of finely crushed material and by increase of uncrushed grains which are grouped close together. As these groups become more numerous, the gneissic banding or streaking gradually fades and a granite results."

As corroborative evidence he says (p. 533) that the minerals of both rocks are the same in many cases, structures are similar, and both intrude the older schists.

In the opinion of the writer, the evidence presented by Fraser (pp. 531-533) does not prove that his granite-gneiss (Bradley granodiorite) is a marginal facies of the San Jacinto granodiorite. The facts that both intrusives have an average composition of granodiorite, and that both intrude the Palm Canyon complex, are not proof. But their notable similarity in mineral composition does at least suggest a fairly close age relationship. The structure and texture of the two rocks are not similar, for, as stated by Fraser (p. 529), the batholithic rock is very generally massive, equigranular, and granitoid with some mineral fracturing, but with little real granulation, while the ''granite-gneiss'' is characteristically highly foliated, inequigranular, and much granulated. The two rock masses, with such contrasting structural and textural features, come close together west and south-southwest of Palm Springs. Such differences do not, of course, positively disprove a close genetic relationship between the two rock masses, but the fact that the ''granite-gneiss'' (Bradley granodiorite-gneiss) shows the same characteristics many miles east of the San Jacinto batholith strengthens the argument for a greater age of the gneiss. But this argument may be more or less

[34] Fraser, Donald M., op. cit., p. 529, 1931.

nullified by the fact that the Bradley granodiorite in the general vicinity of La Quinta is, as already pointed out, distinctly less foliated, sheared, and granulated than usual because environmental conditions were there less favorable for development of such features.

Another fact favoring a distinctly younger age of the San Jacinto granodiorite is that light gray massive dikes of granite (or quartz monzonite), pegmatitic granite, and pegmatite cut both the Bradley granodiorite-gneiss and the Palm Canyon complex sharply, such dikes being reasonably interpreted as offshoots of the batholith. A grand display of such pegmatite and pegmatitic granite dikes may be seen in the granodiorite-gneiss, from west of Palm Springs to Andreas Canyon, within a mile or so of the edge of the batholith.

In order to gain a better understanding of the relationship between the Bradley granodiorite-gneiss and the batholith, the writer examined several places where the two formations come together west and south-southwest of Palm Springs. Thus, following the crest of the spur from west of Palm Springs to Mount Abe Lincoln, the first mile or more shows strongly foliated Bradley granodiorite, dipping steeply away from the batholith, and containing a good many small inclusions or strips of Palm Canyon metasediments, parallel with the foliation, some of them granite-injected before they become xenoliths. There are also some narrow belts of massive, little foliated granodiorite in the gneiss parallel with its foliation. Still closer to the batholithic border, many small pegmatites cut the gneiss—some parallel with its foliation, and others irregularly. Within an eighth of a mile from the batholith, more and larger pegmatites appear, and also some light gray granite dikes. Then there are only xenoliths of the gneiss in granite—both cut by pegmatites—and finally the massive granite or granodiorite of the batholith. Turning now to Andreas Canyon, the first mile up shows typical strongly foliated Bradley dioritic gneiss (fig. 17), containing a large, mapped xenolith of Palm Canyon metasediments, including crystalline limestone. Within less than a mile of the batholithic border the gneiss, with some included metasediments, has been much affected by the batholithic granite which has cut the older rocks to pieces, more or less granitizing and injecting them lit-par-lit resulting in local developments of migmatites and some very crudely banded, strongly foliated gneiss. There are also some dikes of pegmatitic granite. Near the very irregular contact with the generally massive granite or granodiorite of the batholith, the granitic material greatly predominates.

The evidence from the two studies just presented indicates rather strongly that the Bradley granodiorite is distinctly older than, and was largely or wholly foliated (and granulated) before the intrusion of the San Jacinto granodiorite. If it is genetically related to the batholith, it must have been emplaced, and had most of its structure and texture impressed, before the main body of the late Jurassic ? batholithic magma rose into place. The Bradley granodiorite may, however, be still earlier Mesozoic, or even late Paleozoic, in age. This problem is somewhat similar to that involving the age and relation of quartz diorites associated with the Sierra Nevada batholith.[35, 36] The writer has described large

[35] Knopf, Adolf, The Mother Lode system of California: U. S. Geol. Survey Prof. Paper, 157, pp. 10-12, 1929.

[36] Miller, William J., and Webb, Robert W., Descriptive geology of the Kernville quadrangle, California: California Div. Mines Rept. 36, pp. 354-356, 1940.

bodies of quartz diorite distinctly younger than large bodies of granodiorite in the San Gabriel Mountains,[37] and in the Peninsular Mountains of southern San Diego County,[38] and considers them to be not far different in geologic age. After discussing these and other quartz diorites and granodiorites in southern California, the writer has concluded that they are very probably of late Jurassic age. The reader should turn to these discussions because for reasons similar to those there given, the Bradley granodiorite and the San Jacinto granodiorite are believed to be late Jurassic in age.

Fargo Canyon Diorite

The only mapped area of the Fargo Canyon diorite within the Palm Springs-Blythe strip, covers approximately 12 square miles in the Little San Bernardino Mountains east-northeast of Indio as shown on the geologic map (Pl. II). Its extent north of the map limit was not determined. The Fargo Canyon diorite is here so named because of many exposures of the typical rock in Fargo Canyon. For several miles through the canyon, the rock is massive to moderately (crudely) foliated with fairly steep dips. It varies somewhat in grain-size, but it is nearly always medium gray, medium-grained, and uniform in appearance; locally it contains a few anhedral to subhedral hornblendes as much as 6 to 8 millimeters in length. It usually has a few irregularly scattered basic schlieren up to 1 foot in length, and paralleling the foliation.

A thin section of the typical rock from the midst of the area, 2 miles up Fargo Canyon, shows the following minerals by volume percentages: andesine, 58; quartz, 28; orthoclase, 4; biotite, 6; hornblende, 3; magnetite, $\frac{1}{2}$; and small amounts of titanite, zircon, and apatite. The andesine shows some zonal growths. It shows a normal granitoid, allotriomorphic texture. A mile farther up the canyon and nearer the contact with the Chuckwalla complex, the rock has the composition of granodiorite with 20 percent of orthoclase and 9 percent each of hornblende and biotite. In thin section it shows a little granulation of minerals. Pleochroism of the hornblende is bluish green—green—light greenish yellow, and of the biotite dark greenish brown-yellow.

There is no doubt that the Fargo Canyon diorite is much younger than the adjacent Chuckwalla complex (mostly banded gneisses) because the intrusive contact between the two formations is sharp. Such a contact is well shown along the northwestern border of the diorite where it has greatly disturbed and locally contorted the gneisses, and where small dikes of the diorite cut into the gneisses. In Fargo Canyon the diorite contains large and small sharply defined xenoliths of the usually contorted banded gneiss. These xenoliths are very irregular in shape, range in length to 200 feet, and are cut by some small dikes of the enclosing diorite.

Large and small irregular dikelike bodies of massive, medium- to moderately coarse-grained granite or quartz monzonite cut the Fargo Canyon diorite sharply. Eight of these are large enough to be shown on the geologic map (Pl. II), and there may be others about as large. Some

[37] Miller, William J., Geology of the western San Gabriel Mountains of California: Univ. California at Los Angeles, Pub. Math. and Physical Sci., vol. 1, pp. 62-63, 1934.

[38] Miller, William J., A geologic section across the southern Peninsular Range of California: California Div. Mines Rept. 31, pp. 123-128, 1935.

small, scattering dikes of aplitic and pegmatitic granite also cut the diorite sharply. All of these acidic dikes are believed to be offshoots of the large bodies of White Tank monzonite outcropping extensively some miles farther east.

The Fargo Canyon diorite and the Bradley granodiorite in the general vicinity of La Quinta are much alike. Both are massive to only moderately foliated, gray, medium-grained, and granitoid with little granulation of minerals. Both contain considerable amounts of hornblende and biotite with the same pleochroism. In both are some scattered, subhedral hornblendes 5 to 10 millimeters in length. Both look much alike in large outcrops. The main difference is the generally larger amount of potash feldspar including some microcline, in the Bradley granodiorite which varies to quartz monzonite. But other facies of the Bradley are quartz diorite. Both the Fargo Canyon and the Bradley are cut sharply by granite and pegmatitic granite dikes which are offshoots of the White Tank and San Jacinto batholiths, and are regarded as of late Jurassic or early Cretaceous age. For the reasons given, the writer tentatively correlates the Fargo Canyon diorite and the Bradley granodiorite. Since the latter cuts the Paleozoic Palm Canyon complex, both the Fargo Canyon and the Bradley may be as old as late Paleozoic or as young as early Cretaceous, with the probabilities favoring a late Jurassic age for reasons already given in the discussion of the Bradley granodiorite.

LATE MESOZOIC ROCKS

San Jacinto Granodiorite

Granodiorite is shown on the accompanying geologic map (Pl. I), west and southwest of Palm Springs. It has been described by Fraser [39] in his report on the San Jacinto quadrangle where it is very extensively developed, and constitutes by far the main part of his San Jacinto batholith, which includes also his marginal facies ''granite-gneiss.'' Since Fraser has so fully described the rock, and since so little of it shows within the Palm Springs-Blythe strip, some brief statements only will here be made.

According to Fraser (p. 525),

> "The granite of the San Jacinto batholith is a massive, light gray, granitoid rock in which porphyritic varieties are absent. The chief variation consists of differences in the percentages of orthoclase, plagioclase, and quartz, and minor differences in texture. Therefore no striking changes in the character of the batholithic rock can be observed in the field."

On page 529 he says

> "The San Jacinto batholith, composed of granite, is not a true granite throughout. It has granite, quartz monzonite, granodiorite, and quartz diorite facies, and probably has an average composition close to that of a basic granodiorite."

He also says (p. 529):

> "On the whole, however, the rock is relatively free of end-stage or secondary changes, and has had a rather simple history."

Two specimens of the granodiorite were collected by the writer for study from Chino Canyon 3 to 4 miles northwest of Palm Springs. One of these, well away from the contact with the Palm Canyon complex,

[39] Fraser, Donald M., op. cit., pp. 510, 525-529, 1931.

was medium- to moderately coarse-grained, massive though faintly foliated, with anhedral to euhedral biotites and hornblendes. A thin section shows the following minerals by volume percentages: oligoclase (anhedral to subhedral), 58; orthoclase, 10; quartz, 20; biotite, 9; hornblende, 2; titanite, $\frac{1}{2}$; and still smaller amounts of epidote, magnetite, zircon, and apatite. Pleochroism of the biotite is dark brownish to green-yellow, and of the hornblende bluish green—yellowish green—light greenish yellow. The texture is granitoid, nearly equigranular, and hypidiomorphic with almost no granulation of minerals. Another specimen, from near the contact with the Palm Canyon complex, is much the same, but the plagioclase is oligoclase-andesine; and the rock shows some myrmekite, a little allanite, and some granulation of minerals, this texture probably having resulted from some frictional drag, during a late stage of magma consolidation, near the contact with the country rock.

The relationship between the San Jacinto granodiorite and the Bradley granodiorite-gneiss, west and south of Palm Springs, has already been discussed. One fact, however, needs emphasis, namely, the large number of granitic and pegmatitic dikes from the San Jacinto granodiorite which there cut the gneiss. Massive granitic dikes, presumably of the San Jacinto granodiorite, also cut both the Bradley granodiorite and the Palm Canyon complex a good many miles east of the main body of the San Jacinto granodiorite (figs. 19, 20). Fraser [40] gives evidence which indicates a Jurassic-Cretaceous age for the San Jacinto granodiorite. The evidence presented by the writer, in the discussion of the Bradley granodiorite and its relation to the San Jacinto granodiorite, has led to the same conclusion.

White Tank Monzonite

Six areas of the White Tank monzonite, named from a locality 10 miles south of Twenty-nine Palms, lie between Desert Center and Eagle Mountain Camp on the east, and the Little San Bernardino Mountains on the west. They range in size from 2 square miles to more than 15 square miles. There are also various smaller mapped and unmapped bodies which occur as small stocks and large and small dikes.

Megascopically the typical quartz monzonite is light pinkish gray, medium- to moderately coarse-grained, granitoid, contains several percent of mafic minerals (biotite and magnetite), and is very massive, though here and there faint primary foliation may be detected in outcrops. There are some variations to granite and granodiorite. Local facies are somewhat porphyritic. Usually, however, the rock in large masses is remarkably uniform in composition, texture, and structure. Numerous extensive exposures are characterized by big, light brown, rounded joint blocks and boulders of weathering, commonly 5 to 30 feet in diameter. In the field it is strikingly different in appearance from the dark gray, more jagged outcrops of the Chuckwalla complex so extensive in the same region.

Microscopically the typical rock consists mainly of quartz, microcline, oligoclase, microperthite, and, in some cases, orthoclase, together with a small percentage of biotite and magnetite, and about 1 percent of other minerals which usually include epidote, sericite, titanite, zircon,

[40] Fraser, Donald M., op. cit., p. 510, 1931.

apatite, and less often allanite. A little deuteric sericitization and epidotization are common. The texture is nearly always granitoid, equigranular to subequigranular, and allotriomorphic to hypidiomorphic. Granulation of minerals is rare in large bodies of the rock.

A thin section of the rock, from the middle part of the Eagle Mountain aqueduct tunnel 7 miles west-northwest of Desert Center, shows by volume percentages: quartz, 18; microcline, 57; oligoclase, 21; biotite, 2; magnetite, 1; titanite, $\frac{1}{2}$; and still smaller amounts of allanite; epidote, zircon, and apatite. This is a granite. It is light pinkish gray, very massive, moderately coarse-grained, and granitoid, but with a slight porphyritic texture. A section of the rock from the southern part of the same tunnel shows: quartz, 30; microcline 36; oligoclase 30; biotite 2; magnetite, 1; and a little sericite, epidote, apatite, and zircon. It is, therefore, a quartz monzonite. It is coarse medium-grained and typically granitoid. Another section from the same general part of the tunnel is similar in composition to the one last described, but it has less quartz, more biotite, some microperthite, and a little titanite. The feldspars are subhedral to euhedral. Many fractures in the quartz and feldspars have been filled deuterically with magnetite. It is granitoid and hypidiomorphic with a medium-grained groundmass through which are scattered some pinkish potash feldspar phenocrysts 6 to 8 millimeters in length.

A typical specimen from the area 3 miles northwest of Eagle Mountain Camp shows in thin section: quartz, 32; microperthite, 30; oligoclase, 20; orthoclase, 10; microcline, 5; biotite, 1; magnetite, 1; and a little epidote, sericite, myrmekite, zircon, and apatite. It is a massive, pinkish gray, medium-grained quartz monzonite with a granitoid, allotriomorphic, subequigranular texture.

A specimen taken from near the road in the middle southern part of the large area, and typical of that area northwest of Shaver Summit, is a pinkish, massive, moderately coarse-grained quartz monzonite containing 17 to 32 percent each of quartz, microperthite, microcline, and oligoclase together with a little biotite, magnetite, etc. It has a granitoid allotriomorphic equigranular texture.

The quartz monzonite (with microperthite, microcline, and orthoclase) from a large dike west of the mouth of Fargo Canyon shows exceptional textural features in thin section. There is a crude foliation caused by some shearing of quartz grains and much granulation of the quartz and feldspars. There is some crude mortar texture and some good suture texture. Distinct remnants of an original granitoid texture remain. These exceptional features in the White Tank monzonite are end-stage effects probably induced by frictional drag during a late stage of consolidation of the dike magma.

A true granodiorite facies of the White Tank monzonite occurs in the large area south and southwest of Desert Center. A thin section of a specimen from three-quarters of a mile south of Desert Center shows by volume percentages: quartz, 32; oligoclase, 35; microperthite, 25; biotite, 7; magnetite, $\frac{3}{4}$; a small amount of allanite, epidote, and apatite. It is coarse medium-grained, hypidiomorphic, and granitoid. The rock is pinkish gray, massive, and somewhat porphyritic with a few phenocrysts of microperthite 6 to 8 millimeters in length.

All of the large mapped bodies (Pls. II and III) of the massive, nearly uniform White Tank monzonite show sharp contacts against the Chuckwalla complex, indicating the much younger age of the former. Also, various large and small xenoliths of the complex occur in the monzonite, and large and small dikes of the monzonite cut the complex. Thus in the southern part of the mountainous area 6 to 8 miles west of Desert Center, the quartz monzonite contains scattering xenoliths of the Chuckwalla complex as much as 100 to 200 yards in length. They are mostly diorite varying to metadiorite, often with foliated, amphibolitic borders, and often cut to pieces irregularly by small dikes of the monzonite. There are some local suggestions of assimilation, but no banding.

South and southwest of Desert Center, the large body of quartz monzonite shows steep, sharply defined contacts against the Chuckwalla gneisses. This contact is plainly visible from the highway. Near the contact, a few miles southwest of Desert Center, the monzonite is remarkably jointed in great sheets 6 inches to 2 feet thick with a dip of about 70°. Viewed from the highway, these could easily be mistaken for nearly vertical beds of sandstone.

The body of quartz monzonite, about 1½ miles long and separately mapped about 4½ miles southwest of Eagle Mountain Camp, is a large dike cutting the typical Chuckwalla complex sharply and dividing into two prongs on the southeast.

The body of quartz monzonite 4 to 6 miles northeast of Shaver Summit is of the nature of a huge dike several miles long and about a mile wide. It cuts the crudely banded, somewhat porphyritic Chuckwalla complex sharply, in general following the steep-dipping foliation of the complex, but locally cross-cutting the foliation at low angles. On the east side it contains some small inclusions of the complex, and on the west side it sends dikes irregularly into the complex. Near the western contact a number of small, separate, dikelike intrusions of the monzonite cut the Chuckwalla complex, several of them being shown on the map. Similar dikelike intrusions of the monzonite cut the Chuckwalla complex in the Cottonwood Mountains, and the Fargo Canyon diorite in the vicinity of Fargo Canyon. Some of these are also shown on the geologic map. The large body of White Tank monzonite northwest of Shaver Summit contains many large and small xenoliths of the Chuckwalla complex, some of them large enough to be mapped in a general way.

In all important respects, this quartz monzonite is like the writer's White Tank quartz monzonite of the Twenty-nine Palms region [41] to the northwest, but it lacks the numerous aplite and pegmatite dikes. These intrusive bodies come within 15 miles of each other between Shaver Summit and Twenty-nine Palms, and they are doubtless of the same age. Both are probably of late Jurassic or early Cretaceous age and should be correlated with the Sierra Nevada granodiorite, the Lowe granodiorite of the San Gabriel Mountains, the Victorville quartz monzonite, the Cactus granite of the San Bernardino Mountains, the San Jacinto granodiorite, the acidic plutonics of southern San Diego County, and the Coxcomb granodiorite of the present report, all of which are quite certainly post-Mississippian and pre-Upper Cretaceous.

[41] Miller, William J., op. cit., pp. 438-441, 1938.

Coxcomb Granodiorite

The Coxcomb granodiorite is so named because of its typical and extensive occurrence in the middle portion of the Coxcomb Mountains, where it comprises an area of approximately 20 square miles as shown on the geologic map (Pl. III). However, this area of granodiorite extends northward to include all, or nearly all, of the still more extensive northern part of the mountains. The Coxcomb Mountains, 18 miles in length, constitute an impressive feature of the landscape not only because they rise boldly 1000 to 2000 feet above the adjacent desert floor, but also because of the strikingly different appearance of the very light gray granodiorite of the middle and northern portions, and the dark brown, generally somber McCoy Mountains formation of the southern part, the contact between the two being visible for many miles.

The Coxcomb granodiorite of the mapped area is remarkably uniform in composition, structure, and texture; even more so than the White Tank monzonite. Megascopically, a typical specimen, collected near the southeastern border of the mapped area is very light pinkish gray, medium-grained, and massive, but with a faintly developed primary foliation made noticeable by a slight parallelism of mafic minerals. Quartz, feldspars, and some scattered anhedral to subhedral biotite are visible to the naked eye. Under the microscope, this rock shows the following volume percentages of minerals: quartz, 28; oligoclase, 55; microcline, 12; biotite, 4; titanite, $\frac{1}{4}$; magnetite, $\frac{1}{4}$; allanite, $\frac{1}{4}$; and still less zircon, apatite, and sericite. Zonal growths are common in the oligoclase. Pleochroism of the biotite is deep green to yellow. The texture is granitoid and allotriomorphic. Granulation is practically absent, and there is very little evidence of deuteric action.

Dike rocks of the granodiorite, where they cut into the weak, steep-dipping beds of the McCoy Mountains formation along the contact between the two formations, are very different from the general body of the granodiorite. Thus a thin section of such a dike from the western part of the contact, shows by volume percentages: microcline, 50; quartz, 25; acidic oligoclase, 5; sericite, $1\frac{1}{2}$; biotite, $\frac{1}{2}$; magnetite, $\frac{1}{4}$; and finely granulated, indeterminable groundmass, 18. Some of the potash feldspar may be considerably decomposed orthoclase. The texture is holocrystalline and inequigranular, and there is much granulation of the minerals. The quartz is almost entirely granulated. Many large uncrushed cores or remnants of feldspar are left in the granulated quartz and feldspar, giving the appearance of a crude mortar texture. Some irregular zones are more finely granulated than others. Also some of the finely granulated quartz fills cracks in the feldspar. Sericite indicates some deuteric activity. How much of the crushing is protoclastic, and how much cataclastic in origin is uncertain. The fact that the quartz, a late crystallizing mineral, is so badly crushed suggests considerable post-consolidation granulation. Probably the differential stress which caused the crushing, operated during a late stage of magma consolidation and for some time afterward. In any case, the environment was favorable for such stress conditions where the dike material entered the weak McCoy Mountains beds.

EARLIER TERTIARY ROCKS

Quartz Latite Porphyry Dikes

The most interesting quartz latite porphyry dike is plainly traceable without interruption southwestward from near Desert Center for more than 3 miles. Its outcrop dominates a sharply defined, nearly straight, ridge 75 to 200 feet high (fig. 21). It cuts White Tank monzonite vertically and sharply. Its width is 20 to 50 feet. Megascopically the rock is very massive, light greenish gray, fine-grained to very fine-grained, and moderately porphyritic with many subhedral to euhedral plagioclase phenocrysts 3 to 4 millimeters in length, and some elongate chloritized biotite, scattered through the very fine-grained groundmass. The greenish cast of the rock is caused by the chlorite. Probably because of weathering of mafic minerals, the rock nearly everywhere shows a brown layer 1/16 of an inch or less in thickness on the surface even of the very fresh greenish gray rock. A thin section of the rock is seen to be holocrystalline, but much of it is so fine-grained that the following volume percentages of minerals are only rough approximations: acidic andesine, 50; orthoclase, 30; quartz, 14; biotite, 2; sericite, 2; magnetite, $1\frac{1}{2}$; and less than $\frac{1}{2}$ percent each of titanite, apatite, and zircon. The feldspars are badly decomposed yielding numerous sericite flakes, and the biotites have largely been altered to chlorite. The phenocrysts are plagioclase.

The most interesting group of the quartz latite porphyry dikes occurs in the face of the mountain between 5 and 6 miles west-northwest of Desert Center. Six of them are represented on the geologic map (Pl. III). They range in length from $\frac{1}{2}$ to 1 mile, and in width from a few feet to 25 or 30 feet. Some of them cut the Chuckwalla complex, and others cut the White Tank monzonite. Contacts are sharp and steep. A specimen from the interior of one of the large dikes cutting the Chuckwalla complex is megascopically like that of the dike near Desert Center, but it is not quite so fine-grained. Mineralogically there is some difference, a thin section showing: quartz, 20; microcline, 34; oligoclase, 10; myrmekite (quartz and oligoclase), 28; biotite, 2; sericite, 2; magnetite, $1\frac{1}{2}$; and garnet, $\frac{1}{2}$. Because of the fine grain of the groundmass, most of the percentages given are only rough approximations. Quartz, microcline, and plagioclase form anhedral to subhedral phenocrysts 1 to 3 millimeters in length, and they constitute about 15 percent of the section. The quartz phenocrysts are often rounded and locally embayed as a result of magmatic corrosion. There is much evidence of deuteric action.

Megascopically and microscopically a specimen from one of the dikes 4 miles east of Desert Center is very similar to the one last described, but it contains in addition a little epidote.

Two quartz latite porphyry dikes occur in the McCoy Mountain formation near its contact with the Coxcomb granodiorite in the Coxcomb Mountains. It is holocrystalline, but very fine-grained. In thin section it shows definitely considerable quartz, orthoclase, and acidic andesine as tiny phenocrysts, myriads of sericite flakes, scattered tiny grains of magnetite and pyrite, and a large amount of groundmass too fine-grained for accurate determination, but which seems to be mainly plagioclase, orthoclase, and quartz.

A specimen from one of the dikes in the Maria Mountains, $4\frac{1}{2}$ miles east-southeast of Cox, is a very fine-grained quartz latite porphyry which contains considerable chlorite derived from hornblende, and 3 percent each of secondarily formed epidote and calcite, and a little zircon. The dikes of the group 5 miles north-northwest of Eagle Mountain Camp, and the dike more than a mile in length a few miles northwest of Shaver Summit are simliar to the ones already described.

The quartz latite porphyry dikes are certainly much younger than the late Jurassic? White Tank monzonite. In a number of places the writer found these dikes in close proximity to the basic (andesitic) dikes described under the next caption, but in no case was one kind found actually cutting the other. Their similarity in regard to size, mode of occurrence, and texture suggests that the quartz latite dikes and the basic dikes are not very different in age. Several of the basic dikes in the Mecca Hills do not cut the late Tertiary sediments. Rhyolitic dikes, much like the quartz latite porphyry dikes, cut fine-grained basic dikes in the Twenty-nine Palms region [42] and both are there quite certainly older than late Tertiary sediments, and younger than late Jurassic? monzonite. In the mountains south of Needles, the writer [43] has found quartz latite porphyry dikes, remarkably like those of the Palm Springs-Blythe strip, cut sharply by fine-grained basic dikes, both of them of early or middle Tertiary age. The quartz latite porphyry dikes are, therefore, believed to be of early or middle Tertiary age.

Basic (Andesitic) Dikes

These dikes have been found within four large and small, widely separated areas in the Palm Springs-Blythe strip. On the geologic maps (Pls. II, III, IV) they are rather arbitrarily represented, no attempt having been made to delimit them in detail.

The greatest display of these dikes is in the eastern part of the Eagle Mountains in the general vicinity of Eagle Mountain Camp. A specimen from one of these typical dikes, cutting the Chuckwalla complex $2\frac{1}{2}$ miles south-southeast of Eagle Mountain Camp, is dark gray and fine-grained to very fine-grained. A thin section of it shows: andesine, 70; hornblende, 25; epidote, 2; magnetite, $1\frac{1}{4}$; titanite, 1; apatite, $\frac{1}{4}$; and zircon, $\frac{1}{4}$. It is holocrystalline and inequigranular. The hornblende, with light yellowish green to pale yellow pleochroism, is rather uniformly distributed as numerous small prisms and cross-sections, often euhedral. The secondary epidote occurs as tiny grains and clusters of grains. Similar dikes west and southwest of Eagle Mountain Camp, are, in some cases, porphyritic with plagioclase phenocrysts 1 to 2 millimeters in length. A dike cutting the White Tank monzonite 3 miles northwest of Eagle Mountain Camp is dark gray, very fine-grained, and uniform. In thin section it shows: acidic andesine in the form of euhedral laths, 64; hornblende with light greenish brown to pale brownish yellow pleochroism, 12; chlorite derived from hornblende, 10; epidote in large and small grains, 6; magnetite grains, 5; quartz, $2\frac{1}{2}$; and secondary calcite, $\frac{1}{2}$. The rock in the dike cutting White Tank monzonite $1\frac{1}{4}$ miles southeast of Desert Center is very similar to the one last described, but it is porphyritic with plagioclase phenocrysts 1 to 2

[42] Miller, William J., op. cit., p. 444, 1938.
[43] Miller, William J., op. cit., pp. 121-122, 1944.

millimeters in length. Another similar dike cuts the Chuckwalla complex 4 miles a little south of east of Desert Center. It contains about 30 percent of hornblende, some of it as euhedral crystals several millimeters in length, and a few rounded (partially resorbed) quartz grains, set in a very fine-grained dark gray groundmass. The two basic dikes cutting the Chuckwalla complex in the Mecca Hills; the various ones cutting the Maria? formation in the Maria Mountains; and a group of them cutting the Chuckwalla complex in the Mule Mountains, just south of the map border (Pl. IV) are much like those above described as occurring in the general vicinity of Eagle Mountain Camp. Harder [44] has described the occurrence of andesite porphyry dikes in the iron-ore belt of the Eagle Mountains. They no doubt belong in the same category as the basic (andesitic) dikes of the present report.

In the preceding discussion of the age of the quartz latite porphyry dikes it was pointed out that they and the basic (andesitic) dikes are very probably of about the same age, that is, early or middle Tertiary. In the Mecca Hills the two basic dikes are certainly older than the late Tertiary sediments. One of the dikes, 2½ miles south-southeast of Eagle Mountain Camp, ends abruptly at the base of the late Tertiary (or early Quaternary) olivine basalt. The basic dikes are much younger than the late Jurassic? White Tank monzonite.

LATER TERTIARY ROCKS

Sedimentary Formations

Sedimentary formations of later Tertiary age, with slight exceptions, constitute the extensive Mecca Hills and Indio Hills (Pls. I, II). According to Buwalda and Stanton [45]

> "The upper part of the Indio Hills block is constituted of two formations. One of these is marine and is doubtles correlative of the Carrizo formation [Woodring's Imperial formation] * * * It outcrops in the Indio Hills as small areas at several localities both east and west of the mouth of Thousand Palms Canyon, and in the northern part of the hills. It consists of yellow clays with some sandstone and conglomerate."

Within the Palm Springs-Blythe strip, these marine beds, containing oyster shells and other fossils, occur only in the Indio Hills east of Edom. The age of this formation, with its associated volcanic rocks at its type locality in Carrizo (or Coyote) Mountain in western Imperial County, has been variously interpreted by paleontologists. It has been called Pliocene (probably upper Pliocene) by Vaughan,[46] Miocene or Pliocene (probably the latter) by Gale,[47] and Miocene by Woodring.[48] The difficulty arises because some of the fossils are similar to late Tertiary forms farther north in California, others are related to those of Florida and the West Indies, while still others are distinctive of neither region. In the opinion of the writer, the association of volcanic rocks, including olivine basalt, with the Carrizo formation at its type locality points to an age not greater than middle or late middle Miocene because wide-

---

[44] Harder, Edmund C., op. cit., pp. 51-52, 1912.
[45] Buwalda, John P., and Stanton, W. Layton, op. cit., pp. 104-105, 1930.
[46] Vaughan, Thomas W., Reef-coral fauna of Carrizo Creek, Imperial County, California, and its significance: U. S. Geol. Survey Prof. Paper 98, p. 369, 1917.
[47] Grant, U. S. IV, and Gale, Hoyt R., Pliocene and Pleistocene Mollusca of California: San Diego Soc. Nat. Hist. Mem., vol. 1, pp. 50-51, 1931.
[48] Woodring, Wendell P., op. cit., pp. 14-25, 1932.

spread Tertiary volcanics are seldom if ever older than that in southern California. The weight of evidence, then, seems to favor an upper Miocene or Pliocene (probably the latter) age of the marine Carrizo (or Imperial) formation.

According to Buwalda and Stanton,[49] an arid-climate, terrestrial formation, several thousand feet thick, rests upon the marine Carrizo beds, probably by unconformity, in the Indio Hills. They call it the Indio formation. It consists of clays, arkosic sandstones, and fanglomerates, all moderately indurated. Buwalda and Stanton suggest that the age of the formation is not greater than middle Miocene and not less than lower Pliocene. But if the Carrizo beds are as young as lower Pliocene, then the thick Indio formation would be upper Pliocene or possibly lower Quaternary.

The marine Carrizo formation has not been found in the Mecca Hills which, with the exception of some small inliers of crystalline rocks, consist entirely of non-marine beds doubtless of the same origin and age as the Indio formation. According to Mendenhall [50] the formation is 4,000 to 5,000 feet thick in the Mecca Hills where it consists of only moderately consolidated conglomerates, brownish-red and yellowish sandstones, including arkosic sandstones, and soft shales (fig. 22). Brown [51] says that

> "Conglomerate occurs as a basal member wherever the Tertiary beds rest on older rocks, and usually consists of fragments of the underlying bedrock. As a rule the conglomerate grades laterally into sand (sandstone) and clay (shale) away from the crystalline bedrock. This gradation is well exhibited in Shaver Canyon where the conglomerate is coarse at Shaver Well, but much finer 2 or 3 miles away. Doubtless there is also a vertical gradation, the strata at the bottom near the bedrock surface being much coarser than the succeeding strata above."

The Tertiary strata in both the Indio and the Mecca Hills are strongly folded and faulted. According to L. F. Noble, as reported by Darton,[52] the strata in both hills

> "* * * are folded in compressed anticlines and synclines, which in general are parallel to the trend of the hills, but the strike is somewhat more to the north and the beds are cut off diagonally by the San Andreas fault which passes along their south side."

Folding and faulting have no doubt been contemporaneous.

Olivine Basalt

Four occurrences of olivine basalt are represented on the Desert Center map area (Pl. III) in the general vicinity of Eagle Mountain Camp. In all cases the basalt occurs as small isolated portions of lava-flows capping parts of ridges or hills. The largest area is 7 to 8 miles north-northeast of Eagle Mountain Camp. The small area across the little valley just to the east was formerly connected with it. Most of the lava is there nearly black, but some is reddish brown. Some is dense and aphanitic, but most of it is vesicular and in part amygdaloidal. At least three beds of crudely stratified, reddish sands, 50 to 100 feet thick, are intercalated with the lava-flows. The lavas and sands, prob-

---

[49] Buwalda, John P., and Stanton, W. Layton, op. cit., p. 105, 1930.
[50] Mendenhall, Walter C., op. cit., pp. 12-13, 1909.
[51] Brown, John S., op. cit., p. 45, 1923.
[52] Darton, Nelson H., op. cit., p. 259.

ably 500 to 700 feet thick, dip about 15° S. A thin section of the lava shows by volume percentages: basic andesine, 68; augite, 20; olivine, 7; magnetite, 5; and limonite stains. The andesine occurs as tiny subhedral laths; much of the augite as tiny euhedrons; and the olivine as small, subhedral phenocrysts with serpentine-filled cracks. The feldspar laths show a crude flow-structure around the olivines.

The somewhat vesicular dark gray basalt from the small lava-cap 4 miles north-northwest of Eagle Mountain Camp is similar in composition and texture to the rock last described, but it contains about 20 percent of olivine and some amygdaloidal calcite. A number of olivine phenocrysts, 2 to 3 millimeters in length, vary from subhedral to deeply corroded and embayed. Many of the olivines show partial or complete alteration to iddingsite, the latter often in the form of wide rims.

The lava-cap 3 miles southeast of Eagle Mountain Camp consists of dark gray, vesicular, gently dipping, basaltic flows with a total thickness of several hundred feet. In thin section the rock is very similar to that already described from the area 7 to 8 miles north-northeast of Eagle Mountain Camp, but with important differences in the lack of augite and the larger amount of andesine. This lava poured out on a very irregular surface of the Chuckwalla complex. One of the already described late Tertiary basic (andesitic) dikes comes to the old erosional surface, but it does not cut the olivine basalt, thus proving the latter to be distinctly the younger, that is late Tertiary, or possibly early Quaternary.

QUATERNARY DEPOSITS

Unconsolidated Quaternary deposits cover nearly all of the lowlands and the more important valleys which occupy more than half the area of the Palm Springs-Blythe strip. With few exceptions, such deposits effectually conceal the bedrock formations. This alluvium is a heterogeneous lot of material consisting of boulders, gravel, sand, and fine silts or clays. It includes angular, subangular, and fairly well-rounded rock fragments ranging in size from several feet in diameter to the finest silt. All of this alluvium has been and still is being washed down from the mountains and more or less stratified by water, the coarsest material being deposited near the mountain bases and the fine, well-stratified silts far out in the intermont basins. Some is lake-bed material, and some has been reworked by the wind.

Brown [53] says that

"The thickness of this Quaternary valley fill is highly variable. At the mountain borders it thins to the vanishing point, but in the larger valleys it reaches a thickness of at least several hundred feet. The Hopkins well, near the center of Chuckwalla Valley, penetrated sand and gravel, and reached bedrock at 1,200 feet. Much of this material was doubtless Quaternary, though Tertiary beds, similar to those found elsewhere in the region, would probably be indistinguishable from the Quaternary in drilling and may be present beneath the Quaternary at that place. A considerable number of wells in Coachella Valley exceed 1,000 feet in depth, and, so far as reported, none of them reached bedrock. A part of this depth, however, may be in Tertiary material."

[53] Brown, John S., op. cit., p. 48, 1923.

STRUCTURAL FEATURES

Various geologic structures, referred to in the preceding discussions, will not again be mentioned here. The metamorphic, sedimentary, and volcanic rocks of all ages, excepting the Quaternary, everywhere show foliation or bedding dips ranging from horizontal to vertical, with dips of 15° to 50° very common. The Chuckwalla complex shows many complicated and variable structures. All of the Paleozoic metamorphic formations show not only strong dips, but often also folded structures the most complicated of which characterize the Palm Canyon complex. The late Tertiary sediments in the Indio Hills and Mecca Hills are folded into compressed anticlines and synclines.

Contacts of the late Mesozoic plutonic rocks against the country rocks are nearly everywhere sharp, very steep, and cross-cutting. The Bradley granodiorite sometimes exhibits sill-like relationships to the Palm Canyon complex. Contacts of the Tertiary dikes against the country rock are also sharp, very steep, and cross-cutting.

There is a strongly prevalent northwesterly trend of mountain ranges, ridges, and valleys, the principal exceptions being the Eagle Mountains and the long, narrow, east-west valley extending from Cactus City to Desert Center. Nearly all mapped areas of important formations, ranging in age from early pre-Cambrian to late Tertiary, show a similar northwesterly trend. Foliation, stratification, folds, and even the more important xenoliths, also nearly all show a general northwesterly strike. Evidently there has been a strong tendency for stresses to be repeated in the same general direction from early pre-Cambrian time to the present.

The great San Andreas fault zone cuts diagonally across the Palm Springs-Blythe strip for about 28 miles. It strikes northwesterly through the eastern side of the Coachella Valley (Pls. I, II). It continues northwestward for hundreds of miles, and southeastward at least as far as the base of the Chocolate Mountains. The main fault follows the southeastern bases of the Indio Hills and the Mecca Hills where, along its trace, the late Tertiary strata are highly disturbed and badly crushed. The important Mission Creek fault, branching off the San Andreas fault north-northwest of Indio, cuts diagonally through the Indio Hills. Another fault branches off the main San Andreas fault in the southeastern part of the Indio Hills and extends southeastward through the midst of the Mecca Hills, as shown on the accompanying geologic map. It is roughly parallel to the main fault and here forms an important part of the San Andreas fault zone. It may be called the Mecca Hills fault. A little hill of disturbed Tertiary strata marks its course 4 miles east-northeast of Indio. Where the main highway crosses it, 6½ miles a little south of east of Indio, Quaternary beds are much disturbed. About 2½ miles southeast of the last named point, the fault trace is marked by disturbance of late Tertiary beds. It is plainly evident where it crosses Painted Canyon and also Shaver Canyon just south of the map limit. It is believed to continue southeastward through Hidden Spring and Dos Palmas Spring. In Painted Canyon a branch of this fault runs to the southeast at a low angle and across Shaver Canyon. The traces of the three important faults just described,

especially in the Indio Hills, are, at various places, marked by springs around which are clusters of palm trees.

An important fault forms the northeastern boundary of the Mecca Hills. Along the highway 2 miles west of Cactus City, the crystalline rocks are badly crushed to a fault breccia with a northwesterly strike. It doubtless continues northwestward along the base of the Little San Bernardino Mountains where it is largely or wholly concealed by alluvium. Just north of Shaver Well the fault is evident where the late Tertiary beds, with inliers of crystalline rocks, rise sharply above the adjacent, wide, Quaternary wash. The fault runs under part of this wash and into the Orocopia Mountains where it separates the Orocopia schist from the Chuckwalla complex. Its extent beyond that was not determined. Branching off this fault a little northeast of Shaver Well, a shorter fault strikes south-southeast to join the Mecca fault near Hidden Spring. It separates the Orocopia schist from the Tertiary beds of the Mecca Hills. This fault, which may be called the Little San Bernardino fault, may also be considered as part of the San Andreas fault system.

It is generally agreed among geologists that the extensive, wedge-shaped, largely below-sea-level basin, including Imperial Valley, Salton Sea, and Coachella Valley, is a structural basin of the general nature of a relatively sunken fault block. Coachella Valley is bounded on the northeastern side by the Little San Bernardino and Orocopia Mountains, and on the southwestern side by the San Jacinto and Santa Rosa Mountains. All of these mountains rise thousands of feet above the valley floor. The San Andreas fault zone, including the Little San Bernardino fault, plainly marks the eastern side of the Coachella Valley with greatest uplift along the northeastern side of the Little San Bernardino fault. The Indio Hills and the Mecca Hills are there of the nature of down-stepped foothills sliced by the more recently active members of the San Andreas fault zone. In the vicinity of Palm Springs, the valley is bounded by the San Jacinto Mountains which there rise abruptly and very impressively to a height of 10,000 feet above the valley floor. These mountains represent the upthrow side of the Palm Canyon fault. The warm springs in the city of Palm Springs no doubt emerge along this fault. The Santa Rosa Mountains, here taken to include the whole mountainous area extending from a few miles southeast of Palm Springs to the west of the northern part of the Salton Sea, form most of the southwestern border of Coachella Valley. The middle and southern parts of the Santa Rosa Mountains constitute a distinctly tilted fault block uplifted fully 6,000 feet along its steep southwestern side where it is bounded by the still active San Jacinto fault. A longer, less steep down-slope characterizes the northeastern side of the block. The northern part of the Santa Rosa Mountains, partly shown on the accompanying map (Pl. I), is not so distinctly tilted, but it is, rather, a mass down-dropped sharply against the San Jacinto Mountains along the Palm Canyon fault. The boundary between the Santa Rosa Mountains and Coachella Valley is very irregular, particularly from the vicinity of La Quinta to Cathedral City. Nothing like a clearly defined fault or fault zone could be found along this boundary within the map limits of the present report where, if such a fault (or fault zone) exists, it is effectually buried under heavy alluvium. Farther south the fairly straight,

steep scarp suggests border-zone faulting, but the writer has not examined that area. One explanation of the lack of sharply defined border-zone faulting is that the faulting may be relatively old so that the fault scarp has since been cut back irregularly and deeply fan-bayed. Another possibility is that the down-tilted surface of the Santa Rosa Mountains extends well out under the thick alluvium of Coachella Valley in a manner similar to that of the Sierra Nevada block on the San Joaquin Valley side, and involves little or no border-zone faulting. In any case Coachella Valley is definitely a structural basin with its bedrock floor deeply buried under alluvium which in places exceeds a thickness of 1,000 feet.

The long, narrow, eastward-trending valley, extending from Cactus City many miles eastward to near Desert Center, is distinctly exceptional to the northwesterly trend of the other important valleys in the Palm Springs-Blythe strip. This valley cuts across the trend of mapped areas of the Chuckwalla complex and White Tank monzonite and of foliation of the metamorphics and xenoliths in the monzonite. The south front of the Eagle and Cottonwood Mountains, facing the valley, rises steeply to a height of 2000 to 3000 feet, while north of the scarp the surface is plateau-like and little dissected. Facing the valley on the south, the Orocopia and Hayfield Mountains, and in part the Chuckwalla Mountains, are generally much lower, less steep, and deeply embayed. Without much doubt, this is a structural valley. The writer agrees with Brown [54] who says that the evidence strongly supports the theory that a fault (or fault zone) extends through the valley; that the mountains on the north form the upthrow side; that the mountains on the south not only form the downthrow side, but also that they are down-tilted toward the fault. If present, the fault is nowhere visible, being concealed under the valley alluvium.

The Coxcomb Mountains and the long, eastern ridge of the Palen Mountains, both suggest by their shapes that they are fault blocks with faults near their western fronts and with downtilts toward the east. The long, straight, northeastern front of the McCoy Mountains, and the long, straight, southwestern front of the Maria Mountains, both strongly suggest that important faults occur not far out from those mountain bases. All four cases mentioned are in the eastern half of the Palm Springs-Blythe strip where the region is in a late mature stage of the desert cycle of erosion, and where there has been little active faulting in late Quaternary times, so that any older faults are largely or wholly buried under alluvium.

Many examples of minor faulting were observed within the mountains, but no attempt was made by the writer to show these on the maps.

[54] Brown, John S., op. cit., pp. 53, 238, 1923.

GEOLOGY OF PARTS OF THE BARSTOW QUADRANGLE, SAN BERNARDINO COUNTY, CALIFORNIA

By William J. Miller *

OUTLINE OF REPORT

ABSTRACT

The Barstow quadrangle lies in middlewestern San Bernardino County, California. The two parts of the quadrangle described in this report cover nearly 400 square miles (Pls. V and VI). Within the two areas, altitudes range from a little less than 2100 feet to more than 4500 feet. Numerous desert hills and mountains, separated by relatively wide desert basins, rise to heights ranging from a few hundred feet to nearly 2000 feet above the surrounding country. The Mojave River flows across both map areas.

The oldest rocks are metasediments, mainly crystalline limestones, together with some quartzites and schists. These are cut by dioritic and granitic rocks. Where the metasediments greatly predominate, the combination is called the Hinkley Valley complex, and where the plutonics predominate, the combination is called the Hodge complex. These oldest rocks are either Paleozoic or pre-Cambrian in age, probably early pre-Cambrian. They occur only in the Barstow map area.

The Oro Grande crystalline limestone and quartzite are found in several parts of the Victorville map area. Enough fossils have been found to prove the late Paleozoic (probably Mississippian) age of the formation.

In the Victorville map area, the Sidewinder Valley metavolcanics are well exhibited in a number of localities. These consist of original

* Professor of Geology, University of California, Los Angeles. Manuscript submitted for publication January 17, 1944.

lavas and tuffs which have been highly altered and usually strongly foliated. In some places they are interbedded with the late Paleozoic Oro Grande metasediments.

Plutonic rocks, probably of late Jurassic age, include massive dioritic and granitic rocks, which cut the late Paleozoic metasediments sharply. Quartz diorite occurs in several parts of the Victorville map area; gabbro-diorite is confined to one important occurrence in the Barstow map area. Most extensively developed of the plutonic rocks is the Victorville quartz monzonite, which is well exposed in a number of small and large areas in the Victorville map area. It has some satellitic dikes of granite, aplite, and pegmatite. It cuts the quartz diorite, but it is probably not much younger.

Quartz latite porphyry dikes of Tertiary age were found cutting the country rocks sharply in five widely separated localities in the Barstow and Victorville map areas.

Three fairly large and a number of small areas of Tertiary volcanic rocks occur in the Barstow and Victorville areas. They include both lavas and pyroclastics, ranging in composition from andesite to rhyolite.

An older alluvium of earlier Quaternary age has been observed at a number of places, the largest mapped area being south of Barstow. It consists of poorly sorted, angular to subangular rock fragments ranging to a foot or more in diameter. The various areas represent erosional remnants of once much more extensive deposits.

Lake beds of Quaternary age were found at a number of widely separated localities. Whether or not these beds are all of the same age and represent deposition in a single large lake, or in smaller lakes of the same or different ages, was not determined.

Younger alluvium of late Quaternary age, consisting of various kinds of mantle rock still in process of deposition, is widely distributed over the valley floors.

The principal topographic features were produced by block faulting during early and probably middle Quaternary time. Since then the small mountain blocks have been much modified by erosion, sharply defined fault scarps have been obliterated, and alluvial cones and fans have spread widely over the intermont basins.

The Mojave River has recently trenched the alluvial deposits to a depth of 100 to 200 feet across the Barstow quadrangle. At two places near Victorville the river, during its down-cutting, encountered buried ridges of quartz monzonite into which it has been forced to cut narrow gorges.

ACKNOWLEDGMENTS

The accompanying maps (Pls. V and VI) comprise the regions geologically mapped for the present report. Data for the base maps used, including the contours, were taken from the Barstow quadrangle published by the United States Geological Survey.

Field work was carried on mainly during the cooler seasons from 1935 to 1941 as part of a program of study of the crystalline rocks of southern California. It was planned to map the whole Barstow quadrangle, but the war emergency in general, and military activity within the quadrangle in particular, have necessitated indefinite delay in carrying out that plan.

Much of the cost of field and laboratory work was defrayed by grants in aid from the Board of Research of the University of California, Los Angeles. This aid is gratefully acknowledged.

Certain fossil remains, collected by the writer, were sent for age determination to Dr. Winifred Goldring of the New York State Museum, Dr. G. Arthur Cooper of the United States National Museum, and Dr. Edwin Kirk of the United States Geological Survey. This aid is also gratefully acknowledged. Dr. Cordell Durrell of the Department of Geology, University of California, Los Angeles, kindly helped with the interpretation of some of the thin sections.

GEOGRAPHIC AND RELIEF FEATURES

Two parts of the Barstow quadrangle are described in this report. One of these, comprising an area of about 175 square miles, forms the middle-southern part of the quadrangle. This will be known as the Victorville area (Pl. V). The other, comprising an area of about 220 square miles, forms the northeastern part of the quadrangle. It will be known as the Barstow area (Pl. VI). Victorville and Barstow are the only large towns within these areas.

The Mojave River, the Santa Fe Railroad, and the much traveled U. S. Highway 66, all approximately parallel, extend across the western side of the Victorville area, and diagonally through part of the Barstow area.

Another line of the Santa Fe Railroad and U. S. Highway 466 run nearly due east across the middle of the Barstow area. Many other more or less traveled roads make nearly all parts of both areas readily accessible.

The town of Barstow is situated in the middle-western part of the Mojave Desert, and, topographically, the Barstow quadrangle is typical of that extensive desert region. Considerably less than half of the Victorville area, and only about a quarter of the Barstow area, are mountainous or hilly with numerous outcrops of bedrock. The rest of each area is covered with unconsolidated Quaternary deposits.

Within the Victorville area, altitudes vary from 2500 feet to over 4500 feet, and a number of rugged mountains rise boldly 1000 to 1500 feet above the adjacent lowland valley floors which have relatively smooth surfaces, gentle slopes, and altitudes ranging from 2800 to 3200 feet. Highest of all is Quartzite Peak with an altitude of 4531 feet. Across the Victorville map area, the Mojave River has cut a narrow, well-defined valley 200 feet deep into the Quaternary deposits. At and near Victorville the river flows through two short, very narrow gorges which it has cut into crystalline rocks.

Within the Barstow area, altitudes vary from less than 2100 feet to nearly 3300 feet. Several small, moderately rugged mountains rise boldly 500 to 800 feet above the relatively smooth desert floor whose altitudes range from 2200 to 2500 feet. The valley of the Mojave River, cut into Quaternary deposits, is less sharply defined than it is in the Victorville area.

Topographically the Victorville and Barstow areas represent stages varying from maturity to late maturity, or possibly early old age, in the desert cycle of erosion. Alluvial fans everywhere extend out from the mountain bases.

PREVIOUS GEOLOGIC WORK

Surprisingly little has been published on the geology of the Victorville and Barstow areas, particularly on the kinds, origin, distribution, and age relations of the crystalline rocks which comprise the most varied and extensive bedrock formations. Most of the brief records in regard to these rocks are based upon reconnaissance observations, principally near the railroads.

In 1902 Hershey [1] published brief descriptive statements on the "Mesozoic granite" near Victorville, the "Archean ? gneiss" near Barstow, and the "Oro Grande series" of metasediments near Oro Grande.

Baker [2] in 1911 described the Tertiary beds just north of the Barstow map area, and discussed the late Cenozoic history of the western Mojave Desert.

Pack [3] published brief statements on the crystalline rocks north and west of Barstow. A reconnaissance geologic map, accompanying his paper, includes the northern part of the Barstow map area of the present report.

Darton's [4] guidebook for the Santa Fe Route contains two reconnaissance geologic maps (sheets 23 and 24) accompanied by geologic notes on the formations between Barstow and Victorville.

In 1929 Thompson [5] published a paper on the Mojave Desert region with emphasis largely upon the water resources. There are some notes on the physical features of the Mojave Valley between Victorville and Barstow. His small-scale reconnaissance geologic map of the Mojave Desert includes the Barstow quadrangle and gives a general idea of some of the formations within that quadrangle.

Tucker and Sampson [6] published a report in 1930 on the mines of San Bernardino County. Scattered through it are brief notes on kinds of rocks which contain the mineral deposits, including the mines of the Barstow quadrangle. No geologic map accompanies the report.

The 1938 Geologic Map of California [7] covers the Victorville and Barstow areas, but shows little new material.

In an elaborate paper on desert sheetfloods and streamfloods in 1938, Davis [8] gives considerable attention to the mountain area just east of Oro Grande in the Victorville area.

An important paper was published by Gardner [9] in 1940 on the geology of the Newberry and Ord Mountains adjacent to the Barstow quadrangle on the east. A detailed geologic map accompanies the report.

---

[1] Hershey, Oscar H., Some crystalline rocks of southern California: American Geologist, vol. 29, pp. 283, 286-289, 1902.

[2] Baker, Charles L., Notes on the later Cenozoic history of the Mojave Desert region in southeastern California: Univ. California Dept. Geol. Sci., Bull. 6, pp. 333-381, 1911.

[3] Pack, Robert W., Reconnaissance of the Barstow-Kramer region, California: U. S. Geol. Survey Bull. 541, pp. 144-145, pl. I, 1914.

[4] Darton, Nelson H., Guidebook of the Western United States, Part C, The Santa Fe Route: U. S. Geol. Survey Bull. 613, pp. 162-165, sheets 23, 24, 1915.

[5] Thompson, David G., The Mojave Desert region of California: U. S. Geol. Survey Water-Supply Paper 578, pp. 330-393, 424-426, pl. 8, 1929.

[6] Tucker, W. B., and Sampson, R. J., San Bernardino County: California Div. Mines Rept. 26, pp. 202-325, 1930 . . . Rept. 39, pp. 427-549, 1943.

[7] Jenkins, Olaf P., Geologic map of California: California Div. Mines, 1938.

[8] Davis, William M., Sheetfloods and streamfloods: Geol. Soc. America Bull., vol. 49, pp. 1350-1353, 1358, 1381-1382, 1938.

[9] Gardner, Dion L., Geology of the Newberry and Ord Mountains, San Bernardino County, California: California Div. Mines Rept. 36, pp. 257-292, pl. 2, 1940.

PALEOZOIC OR OLDER ROCKS

Hinkley Valley Complex

The name Hinkley Valley complex is here proposed to designate the oldest known rocks within the Barstow and Victorville map areas. Excellent outcrops occur in and around Hinkley Valley. The complex has not been recognized in the Victorville area. It consists very largely of metasediments, mostly crystalline limestones, together with some quartzites and schists. These metasediments are in various places cut, usually parallel to the bedding (and foliation), by dioritic, granitic, pegmatitic, and silexitic material. Such igneous materials are very subordinate in amount, and they are so intimately associated with the metasediments that any attempt to map them separately would be unsatisfactory. They belong in the category of the Hodge complex described under the next caption. Seldom if ever are there sharp contacts between the areas mapped as Hinkley Valley and Hodge.

The low mountain ridge, extending from 2 to 6½ miles southwest of Hinkley, consists very largely of the Hinkley Valley complex as shown on the geologic map (Pl. VI). This area is in part indicated on the state geologic map of 1938. Pure white, medium-grained, dolomitic marble, with bedding fairly well preserved, is by far the predominant rock. There are some interbedded mica schists. A thin section of such a schist shows much quartz, calcite, diopside, and brown augite in small anhedral grains, together with numerous tiny flakes of biotite and muscovite, and few small grains of magnetite and pyrite. Originally it was a calcareous, argillaceous sandstone. Steep dips of the formation, usually 50° to 75°, are generally to the southeast in the middle and southwestern part of the area, curving around to dip east and northeast in the northern part. There are, however, many local strike and dip variations, in some cases due to contortions of the strata. Various small masses of crudely to highly foliated dioritic rocks, and more numerous small masses of highly foliated granitic rocks, cut the metasediments, usually parallel to the bedding. Conservatively estimated, the Hinkley Valley complex of this area shows a thickness of at least several thousand feet.

The Hinkley Valley complex is also excellently exposed in many parts of the area of about 6 square miles from 3 to 5½ miles west-northwest of Barstow. Crystalline limestone predominates greatly. Much of it is nearly white, fine- to almost medium-grained, thick-bedded, calcitic marble, but a good deal of it is very fine-grained, thin-bedded, with alternating white and bluish gray calcitic beds, showing much shearing parallel to the bedding. There is also light greenish gray, medium-grained, impure, dolomitic marble. At one locality there is some highly fractured, brecciated, brown, very fine-grained crystalline limestone with tiny veinlets of magnetite. Most of these limestones show yellowish-brown weathered surfaces. Here, as in the area southwest of Hinkley, some small diorite, granite, and pegmatitic granite sills are scattered through the metasediments. There seems to be a general northwesterly strike of bedding within the area, and dips are usually steep, but there are so many local variations in strike and dip that only a few of the more persistent trends are indicated on the geologic map.

The area mapped as Hinkley Valley complex 2 to 3 miles north-northeast of Barstow comprises mostly crystalline limestone, but it con-

tains more than the usual amounts of intruded dioritic and granitic material belonging with the Hodge complex. A good deal of the limestone of this area is fine-grained, nearly white, calcitic and dolomitic marble with yellowish-brown weathered surfaces. Much of it is, however, very fine-grained, thin-bedded, impure, bluish-gray to nearly white marble. This marble seems to have been somewhat granitized or silicified as shown by the presence of small roundish grains of silica, and of scattered lenslike and irregular-shaped, angular to fairly well-rounded bits of granite, nearly an inch in length, and arranged roughly parallel to the bedding. These granite fragments are no doubt from thin bands of injected granite which have been broken up and the pieces kneaded into the plastic limestone. This limestone, with its granite fragments, and grains of silica, looks very much like a common facies of the crystalline limestone of the Palm Canyon complex described by the writer [10] as occurring southeast of Palm Springs. Similar limestone, containing granite fragments, occurs here and there within the area mapped as Hodge complex 2 to 4 miles north of Barstow. The dip of the Hinkley Valley complex 2 to 3 miles northeast of Barstow is generally steep and to the northwest.

The two small areas of the Hinkley Valley complex a mile or more north of Barstow, and the three small areas north of Lenwood, comprise rather steep-dipping crystalline limestones which have weathered to a yellowish brown. The two small areas about 1½ miles east of Hinkley are steep-dipping, coarse-grained marble. Considerable quartzite is interbedded with the steep-dipping marble 1½ to 2 miles northwest of Hinkley. About 3 miles west of Hinkley a small area of crystalline limestone is cut by considerable diorite and granite.

It is the opinion of the writer that the metasediments of the Hinkley Valley complex are the oldest rocks within the Barstow and Victorville areas. The generally foliated dioritic and granitic rocks of the Hodge complex are definitely younger. Hershey [11] tentatively suggested a pre-Cambrian, probably Archean, age of the schists and gneisses (Hodge complex) west-northwest of Barstow. During the earlier days of field work, the present writer was inclined to accept this interpretation, but it was doubted when the limestones of the Hinkley Valley complex were found to be still older than the igneous rocks of the Hodge complex. Also as already suggested, facies of the Hinkley Valley limestone are remarkably like facies of the Palm Canyon complex, southeast of Palm Springs, which the writer has considered to be Paleozoic or older. The Hinkley Valley complex, like the Palm Canyon complex, is cut in turn by dioritic and granitic rocks. Is the Hinkley Valley complex a correlative of the Oro Grande late Paleozoic metasediments of the Victorville area? Unlike the Hinkley Valley complex, the Oro Grande metasediments have much associated metavolcanic material and quartzite; they are not cut intimately by much-foliated dioritic and granitic material; and their limestone is, in considerable part, different. These differences do not, however, rule out the possibility of their being of the same age. Gardner [12] has found interbedded gneiss, marble, and quartzite associated with dioritic and granitic rocks in the Newberry Mountains east of the Barstow area.

---

[10] Miller, William J., Geology of Palm Springs—Blythe strip, Riverside County, California: California Div. Mines Rept. 40, pp. 21-25, 1944.

[11] Hershey, Oscar H., op. cit., pp. 285-286, 1902.

[12] Gardner, Dion L., op. cit., pp. 262-264, 1940.

Most of the rocks are biotite-orthoclase gneisses. He assigns these rocks to the Archean, but says that this reference is "based upon fragmentary evidence." They may be of Paleozoic or pre-Cambrian age. In some ways these rocks are like the Hinkley Valley and Hodge complexes of the Barstow area, but crystalline limestone is subordinate in them. Near the end of the Bristol Mountains, a few miles east of Amboy, are found pre-Cambrian (probably early pre-Cambrian) rocks including marble cut first by diorite and then by granite. Much less metamorphosed and fossiliferous Cambrian limestone occurs a few miles farther east in the Marble Mountains. In conclusion the writer must be content to assign a middle Paleozoic or greater age to the Hinkley Valley metasediments, with an early pre-Cambrian age most probable.

Hodge Complex

The name Hodge complex is here proposed because of the many good outcrops in the area west of Hodge. As already stated, this complex as mapped is not sharply separable from the Hinkley Valley. It is a complex of igneous and metamorphic rocks consisting very largely of dioritic and granitic rocks together with remnants of the still older Hinkley Valley metasediments (mainly crystalline limestones). Like the Hinkley Valley, so the Hodge complex has not been recognized in the Victorville area. Eleven areas of the Hodge complex are shown on the accompanying geologic map (Pl. VI). The following areal descriptions will give a good idea of the nature of the complex.

The area of 4 or 5 square miles west of Hodge shows numerous outcrops consisting very largely of intimately associated dioritic and granitic rocks, both usually highly foliated, but locally only moderately so. Evidently granite has cut to pieces and locally injected lit-par-lit and digested the metadiorite. There are some amphiboites which may or may not represent metadiorite. Irregularly scattered through the area are remnants of metasediments older than the diorite-granite mixture. Such remnants are presumably parts of the Hinkley Valley metasediments. A good example is a considerable body of quartz-muscovite schist, locally stained with much hematite, near the road 1½ miles a little west of north of Hodge. This schist is cut by much silexite parallel to the foliation. At the western end of the area 3½ miles a little north of west of Hodge, and extending at least 2 miles along the contact with the gabbro-diorite of Iron Mountain, there is a conspicuous outcrop, several hundred yards in width, consisting of hard, very fine-grained quartzite, muscovite schist, and some interbedded brown crystalline limestone. These very steep-dipping beds strike parallel to the diorite contact. Throughout the area dips are generally very steep, and variable in direction. Small aplitic, pegmatitic, and silexitic dikes cut the whole combination.

The long narrow area mapped as Hodge formation 4 to 6½ miles southwest of Hinkley, and the smaller area just east of it, consist largely of a diorite-granite complex, the granitic material predominating greatly. The dioritic material is medium- to fine-grained, and it varies from fairly massive to crudely foliated, highly foliated, sheared, and even schistose. The granitic rocks vary from pinkish-gray, medium-grained, rather massive facies to gray, very biotitic, impure, non-uniform and highly foliated facies. It is evident that the dioritic rock has been cut to pieces, and injected parallel to its foliation, by the granite, the latter having

been rendered impure by assimilation of dioritic material. Contacts are not sharp, and migmatitic banding is seldom well-defined. Small pegmatite and aplite dikes cut the mixed rocks. Similar mixed rocks in small bodies occur at various places throughout the large, adjacent area of the Hinkley Valley metasediments which are mostly dolomitic marble with some interbedded quartz schist. Both the diorite and the granite are plainly younger than the marble, and foliation of the igneous rocks and bedding of the marble are nearly everywhere parallel. The steep dips are generally to the southeast, but there are many local variations.

Rocks much like those just described constitute the two areas mapped as Hodge complex north and northwest of Hinkley.

The area of low hills, between 1 and 3½ miles west-northwest of Barstow, consists of rocks very typical of the Hodge complex, that is, dioritic rocks cut to pieces, injected, and more or less digested by granitic material, the latter predominating. Common facies of the dioritic rocks are dark-gray, medium-grained, massive to well-foliated; dark-gray to nearly black, hornblende-rich, medium- to coarse-grained, and massive, with hornblende crystals an inch or more in length; and gray, highly foliated metadiorite. Common facies of the granitic rocks are pinkish-gray, massive to well foliated medium-grained; light gray, massive moderately coarse-grained, pegmatitic; and medium- to fine-grained, foliated, gray, and impure due to absorbed dioritic material. Banded gneisses occur locally, as for example alongside the road about 2 miles west-northwest of Barstow where contorted thin-banded gneiss has been produced by injection lit-par-lit of schist by pinkish-gray, pegmatitic granite. The schist is either metadiorite, or metasediment, or both. Within the area in general, little recognizable metasediment occurs. Dips are usually very steep and variable. There is no sharp contact between the Hodge complex of the area just described and the Hinkley Valley complex adjacent to it on the northwest, the latter being cut here and there by sills of the Hodge diorite and granite.

The area mapped as Hodge complex, 3 to 5½ miles northwest of Barstow, consists of mixed rocks much like those described in the last paragraph, but outcrops are generally not so good. Much of the granitic material is quartz-rich to silexitic and well foliated to highly foliated. Such silica-rich magma has often intimately injected and replaced the country rock.

The Hodge complex of the area 2 to 4 miles north of Barstow is mostly a complex of the dioritic and granitic rocks already described as so characteristic of the formation, but it contains a good deal of closely associated Hinkley Valley metasediments. It is not sharply separated from the Hinkley Valley complex adjacent to it on the southeast. Fine exposures, typical of the area, are easily accessible, along and east of the road for a mile or so, between 3 and 4 miles north of Barstow. Much fine- to medium-grained, dark-gray, crudely foliated to highly foliated diorite (varying to metadiorite) is cut parallel to its foliation, granitized, and injected lit-par-lit by pinkish granite and pegmatitic granite. Alongside the road a big, fine-grained, aplite dike cuts the complex. In the hills east of the road various small and large lenslike xenoliths of Hinkley Valley crystalline limestones and quartzites occur in the diorite-granite complex parallel to its foliation. These xenoliths, particularly their quartzitic portions, in common with the diorite which cuts them, have been notably injected

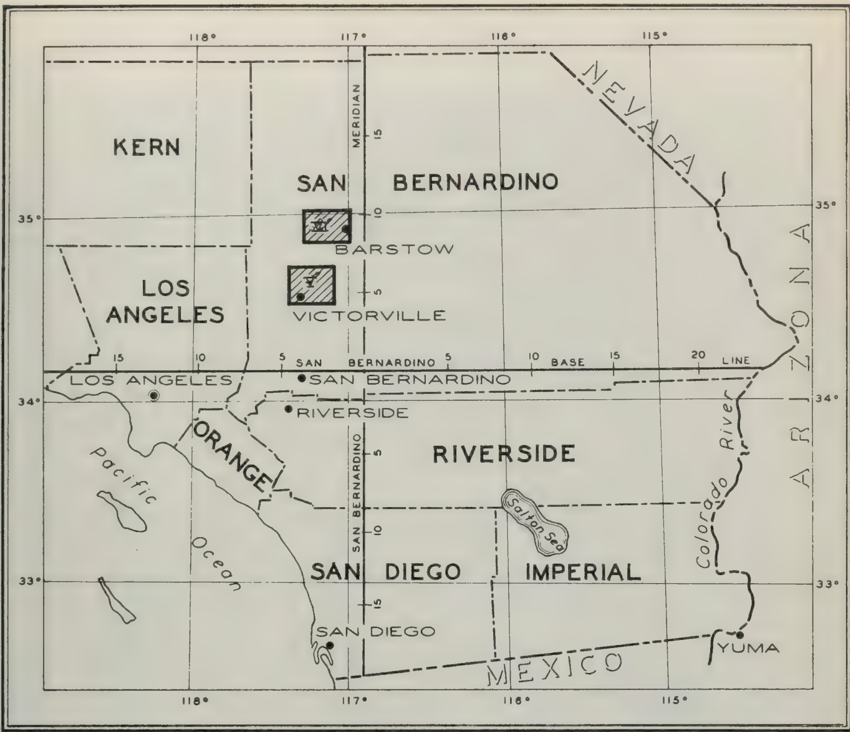


FIG. 1. Index map showing areas covered by accompanying maps, Plates V and VI.

FIG. 2. Steep-dipping crudely bedded crystalline dolomitic limestone of the Hinkley Valley complex. Top of ridge 4¾ miles southwest of Hinkley.

FIG. 3. Hinkley Valley dolomite (in background) cut by variably foliated diorite and metadiorite of the Hodge complex. The diorite is cut irregularly by some small contaminated granite dikes of the Hodge complex. On the ridge 4½ miles southwest of Hinkley.

FIG. 4. Crudely foliated granite of the Hodge complex rendered variably impure by digestion of dioritic material, some xenoliths of which are little affected. The steep-dipping foliation, accentuated by weathering, is cross-cut by a small pegmatite dike. About 5 miles southwest of Hinkley.

FIG. 5. Crudely banded gneiss of the Hodge complex produced by injection lit-par-lit of metadiorite by granite. By the highway $2\frac{1}{2}$ miles west-northwest of Barstow.

FIG. 6. A hill consisting of Oro Grande crystalline limestone. The beds dip steeply to the right. Late Paleozoic fossils were found toward the top of this hill $2\frac{2}{3}$ miles northeast of Victorville.

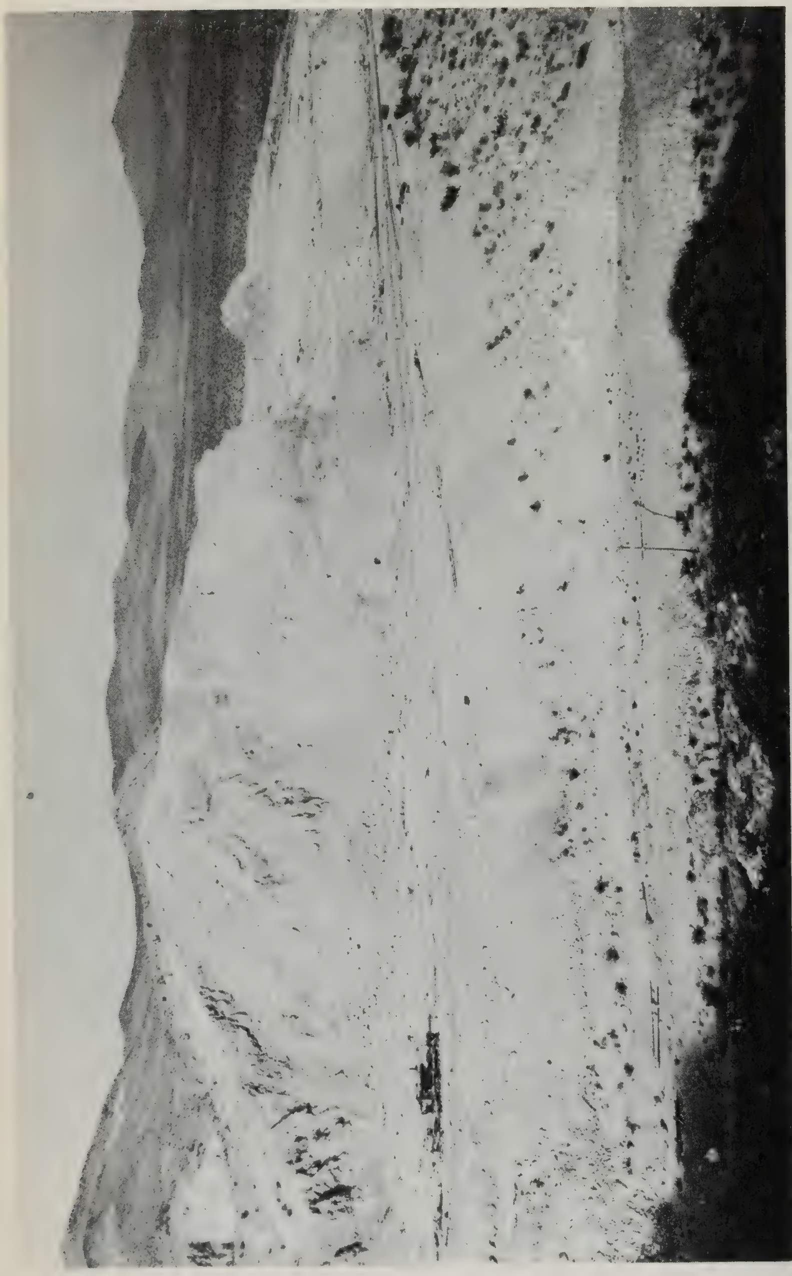


FIG. 7. Oro Grande crystalline limestone in one of the largest quarries owned by a Portland cement company. Six miles a little east of north of Victorville.

FIG. 8. Oro Grande marble (white) cut by small dikes of the quartz diorite of Bell Mountain, in a quarry 3½ miles northeast of Victorville.

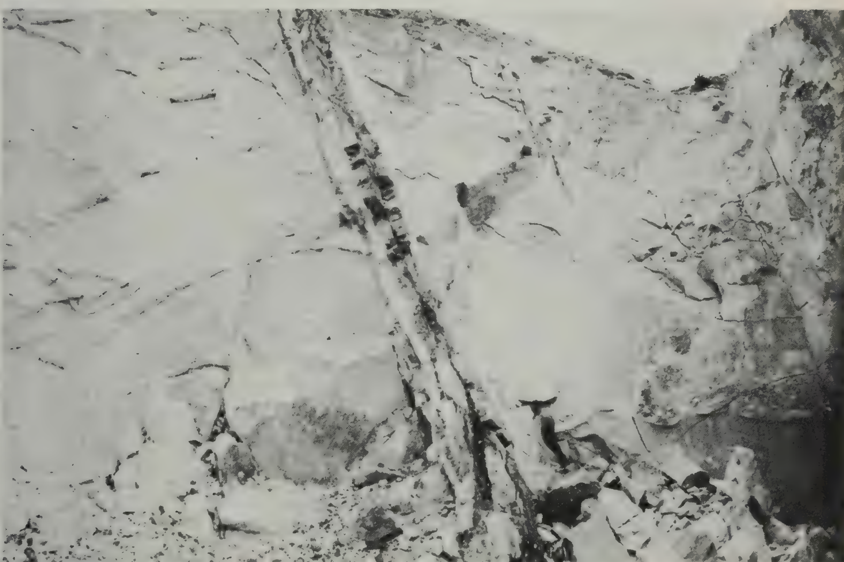


FIG. 9. Detail view of a serpentinized dike of the quartz diorite cutting Oro Grande marble. The dike has chilled borders. In the quarry 3½ miles northeast of Victorville.

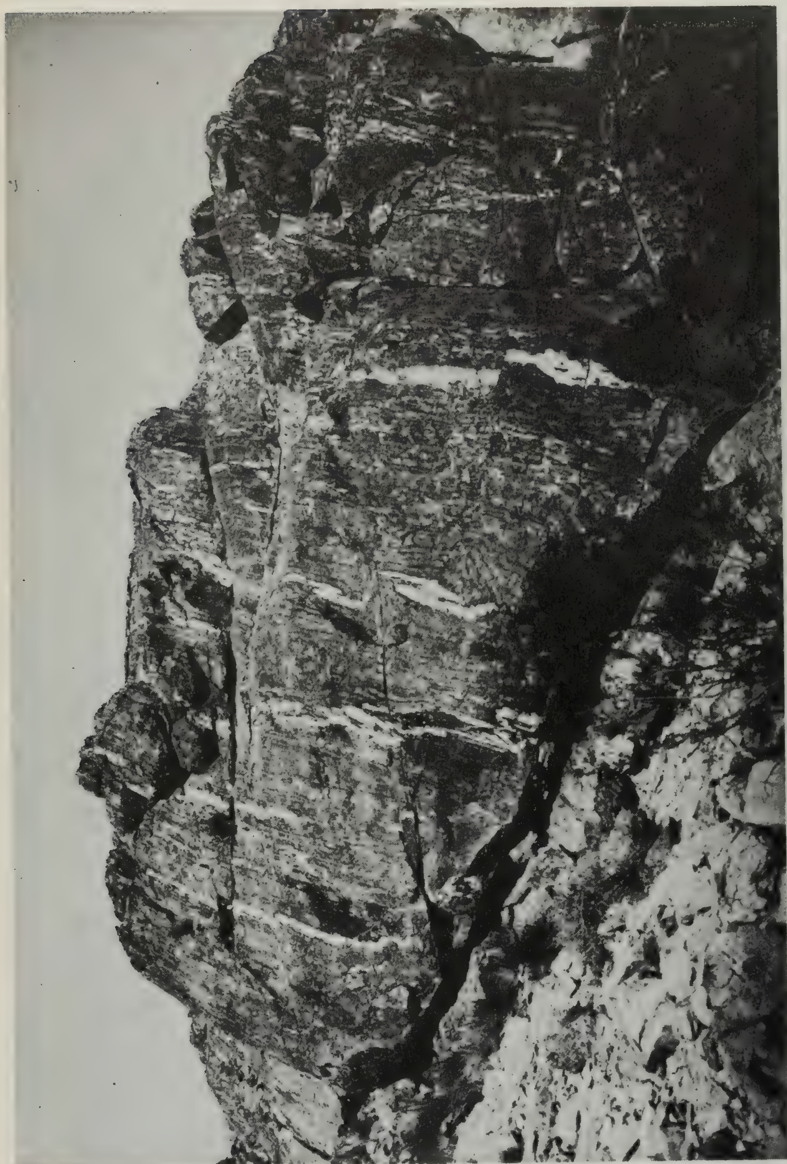


Fig. 10. Detail view of the Oro Grande metasediments, showing steep-dipping, hard, thin-bedded marble and very fine-grained quartzite. Northeast of Victorville 2½ miles.

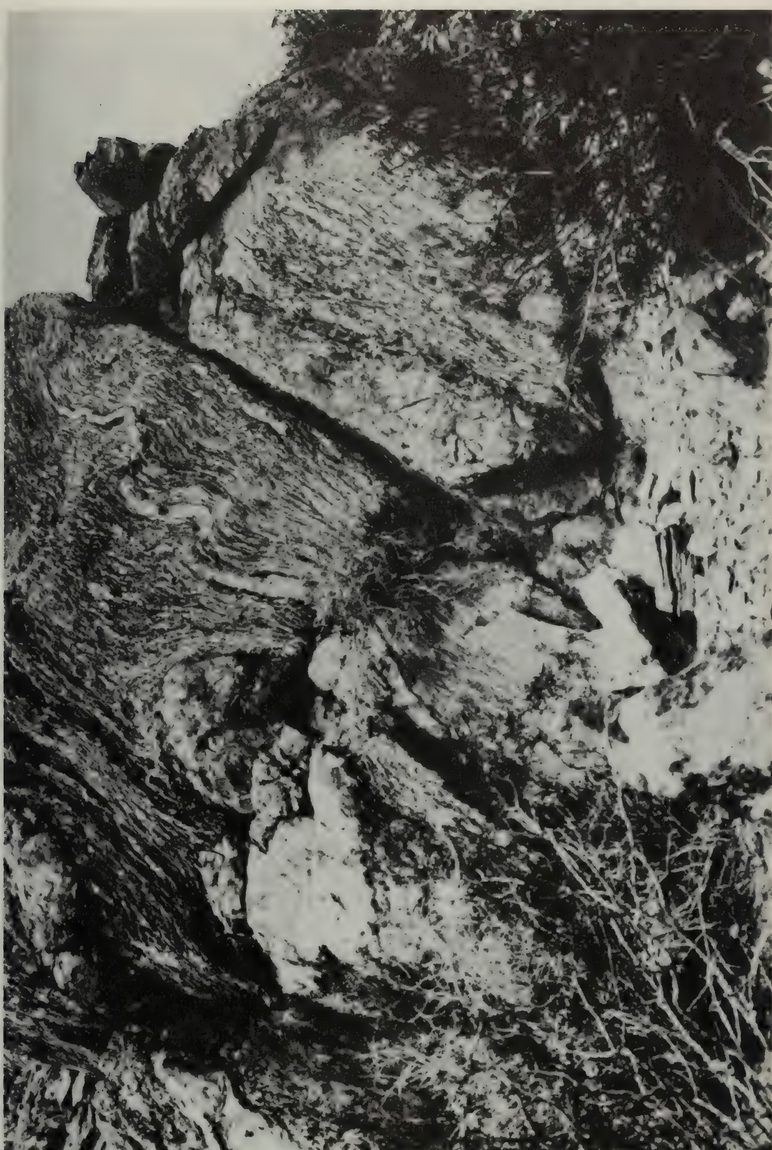


FIG. 11. A detail view of Oro Grande steep-dipping, locally contorted thin-bedded marble, with some interbedded quartzite. Northeast of Oro Grande $1\frac{1}{3}$ miles.

FIG. 12. An outcrop of the Sidewinder Valley metavolcanics showing highly foliated metatuff with nearly vertical dip; 1½ miles a little east of south of Oro Grande.

FIG. 13. A detail view of the Sidewinder Valley metavolcanics showing schistose metatuff with vertical dip. Northeast of Sidewinder Well $4\frac{1}{2}$ miles.

FIG. 14. A crudely jointed pegmatitic granite dike cutting Victorville quartz monzonite. The jointing has been accentuated by weathering. North-northwest of Victorville $2\frac{1}{3}$ miles.

FIG. 15. Xenoliths of mica schist (probably Oro Grande), with vertical dips, in Victorville quartz monzonite. Near the contact between the Oro Grande metasediments and the monzonite $4\frac{1}{2}$ miles north of Victorville.

FIG. 16. A foliated quartz latite porphyry dike cutting quartz diorite. East of Sidewinder Well 4½ miles.

FIG. 17. Strongly tilted Tertiary volcanics including lavas and pyroclastics. The colors are red, brown, yellow, and greenish gray. Northeast of Hinkley 4 miles.

Fig. 18. Quaternary lake deposit including interbedded marl and clay beds. In marl pit 7 miles west-south-west of Hodge.

and granitized by the granite of the Hodge complex. Most of the limestone is very fine-grained, bluish-gray to nearly white, and it contains small, irregularly scattered, subrounded fragments of granite. This limestone is exactly like that already described as occurring 2 to 3 miles northeast of Barstow. Within the area dips are generally steep and to the northwest.

The area 5 to 7 miles north-northwest of Barstow consists of a diorite-granite complex very much like that already described as occurring 1 to 3½ miles west-northwest of Barstow. The same is true of the small area 7 miles south-southwest of Barstow which is the northwestern end of an area of several square miles mostly south of the map limit. All four areas of the Hodge complex shown on the accompanying map (Pl. VI) northwest and north of Barstow are represented as Jurassic granitic rocks on the 1938 state map.

It is evident, from descriptions above given, that both diorite and granite of the Hodge complex are younger than the Hinkley Valley metasediments. As already pointed out, the Hinkley Valley complex has not yielded fossils, and, within the Barstow area, there is no certain evidence upon which a particular age assignment may be based, but it is probably early pre-Cambrian. There is likewise no definite criterion for an age assignment of the diorite-granite Hodge complex, but the writer believes that it, too, is probably early pre-Cambrian.

The much-altered, usually highly foliated granite of the Hodge complex is certainly much older than the generally very massive Victorville quartz monzonite of the Victorville map area where the monzonite cuts the late Paleozoic Oro Grande metasediments, and where no rock at all comparable to the Hodge granite cuts the Oro Grande. The Hodge granite is, therefore, quite certainly older than late Paleozoic.

On the ridge 15 miles south of Barstow, and just southeast of Stoddard Well, a large body of very massive Victorville quartz monzonite sharply cuts, and is much younger than, the Hodge diorite-granite complex.

The Hodge complex is much like similar rock formations generally regarded as early pre-Cambrian in many other parts of southern California, as for examples: the Needles complex [13] of the Needles-Goffs region; the Archean (?) diorite-granite complex [14] of the Newberry and Ord Mountains west of the Barstow area; the Pinto gneiss [15] of the Twenty-nine Palms region; the Chuckwalla complex [16] of middle and eastern Riverside County; the San Gabriel formation [17] in the San Gabriel Mountains; the Johannesburg gneiss [18] of the Randsburg region; and the Archean complex [19] of the Piute and Old Woman Mountains. Hulin

[13] Miller, William J., Geology of the Needles-Goffs region, San Bernardino County, California: California Div. Mines Rept. 40, pp. 116-119, 1944.

[14] Gardner, Dion L., op. cit., pp. 262-263, 1940.

[15] Miller, William J., Pre-Cambrian and associated rocks near Twenty-nine Palms, California: Geol. Soc. America Bull., vol. 49, pp. 424-427, 438, 1938.

[16] Miller, William J., Geology of Palm Springs-Blythe strip, Riverside County, California: California Div. Mines Rept. 40, pp. 16-21, 1944.

[17] Miller, William J., Geology of the western San Gabriel Mountains of California: Univ. California at Los Angeles Pub. Math. and Physical Sci., vol. 1, pp. 49-55, 1934.

[18] Hulin, Carlton D., Geology and ore deposits of the Randsburg quadrangle of California: California Min. Bur. Bull. 95, pp. 21-23, 1925.

[19] Hazzard, John C. and Dosch, Earl F., Archean rocks in the Piute and Old Woman Mountains, San Bernardino County, California: Geol. Soc. America Proc. 1936, pp. 308-309.

does not mention granitic rocks associated with the Johannesburg gneiss, but the writer believes that the metasediments were there first cut by dioritic sills, and that the combination was then cut intricately by granite parallel to the foliation with some resultant migmatitic banding. In nearly all examples mentioned, a highly metamorphosed complex of dioritic and granitic rocks is closely associated with still older metasediments, including crystalline limestones, wihch are probably correlatives of the Hinkley Valley metasediments. In all cases listed, the formations are quite surely pre-Cambrian and very probably early pre-Cambrian.

LATE PALEOZOIC ROCKS

Oro Grande Metasediments

Many years ago Hershey [20] applied the name Oro Grande series to the limestone-quartzite series so prominently exposed in Quartzite Mountain just east of Oro Grande, but he did not map it. Darton's map [21] shows this area in a general way. The series is also conspicuously present northeast of Victorville, and in Sidewinder Mountain, but it has not been found in the Barstow map area. It consists largely of well-bedded, crystalline limestone, considerable quartzite, and small amounts of interbedded sedimentary schists.

The largest mapped area of Oro Grande metasediments covers several square miles east and northeast of Oro Grande. This area is dominated by high, steep Quartzite Mountain which is practically a single great outcrop almost completely barren of vegetation. Many other fine exposures also occur. Most abundant by far are fine- to medium-grained, interbedded, light bluish-gray to white, thin to fairly thick-bedded, calcitic, crystalline limestones with the nearly white varieties most common. Next in importance are fine-grained, nearly white to light greenish-gray, well-bedded to poorly bedded quartzites. A prominent belt of the remarkably pure quartzite, showing little bedding, extends from the south base of Quartzite Mountain northwesterly across its summit. The beds dip 80° SW., and they show a thickness of hundreds of feet. Another important belt of steep-dipping quartzite, hundreds of feet wide, extends 2 miles in a northwesterly direction completely across the eastern part of the area, and in part across the eastern flank of Quartzite Mountain. At various places thin bands of quartzite are interbedded with the limestones. There is also some interbedded biotitic quartz schist. In the big quarries in the eastern part of the area, the rocks are steep-dipping crystalline limestones and fine-grained quartzites in great alternating zones, one of which consists of dolomitic marble, but there is much fine- to medium-grained, nearly white, calcitic, crystalline limestone. There is a little schist, a specimen of which is fine-grained, ash-gray to purplish, variegated, and muscovitic. Strike of the beds is persistently northwestward throughout the area. Dips in the eastern and middle parts of Quartzite Mountain are 70° to 80° SW., and prevailingly 70° NE. in the western part of the mountain, suggesting that the axis of a tightly pinched syncline runs through the western flank of the mountain. In the northern prong of the area the dip is 20° to 30° to the west-southwest. The Oro Grande metasediments of this area must be at least some thousands of feet thick.

[20] Hershey, Oscar H., op. cit., pp. 287-288, 1902.
[21] Darton, Nelson H., op. cit., Sheet 24, 1915.

The area of the Oro Grande metasediments shown on the map (Pl. V), between $1\frac{1}{2}$ and $4\frac{1}{2}$ miles northeast of Victorville, consists predominantly of limestone. Excellent exposures in the sharply defined hill near the middle of the area are nearly all bluish-gray, fine-grained to white, medium-grained, well-bedded, calcitic, crystalline limestones with some interbedded fine-grained, white, to light greenish-gray quartzites, and still less quartz-muscovite schist. Similar rocks occur throughout the area, but in the southern and northern parts, more quartzite is interbedded with the limestone where some of the outcrops show thin, hard, alternating beds of fine-grained, light-gray, crystalline limestone and quartzite. Strike of beds throughout the area is nearly due north with steep dips, ranging from 65° to nearly vertical, to the east in the middle and southern parts, and to the west in the northern part. In the conspicuous hill near the middle of the area, the formation shows an exposed thickness of at least 1000 feet.

Many fine exposures of the Oro Grande metasediments occur throughout the Sidewinder Mountain area as shown on the accompanying geologic map (Pl. V). These are nearly all interbedded crystalline limestones and quartzites much like those of Quartzite Mountain already described. An almost perfect section of the beds is exposed in the southern face of Sidewinder Mountain near the map border where dips are all 75° to the north. At the base of the mountain there is a wide intrusive sheet of diorite. Next comes a wide belt of white to light-gray, medium- to coarse-grained, calcitic, crystalline limestone, together with some white, thin-bedded, sugary, fine-grained, crystalline limestone. It is cut by a number of dikes and sills of diorite and quartz latite porphyry. Above the limestone there is a wide belt of fine-grained, well-bedded, white and pale greenish-gray quartzites which often have reddish brown weathered surfaces. Next in order there is a still wider belt of interbedded quartzite and crystalline limestone, with the former predominating. Finally, a broad belt of bluish gray crystalline limestone forms the top of the mountain. In view of the fact that these steep-dipping, conformable belts are each 1000 to 1500 feet wide, the exposed thickness of the Oro Grande metasediments must be at least 4000 feet in the face of this mountain. Northwest of the section just described the strike of the limestone-quartzite swings to the northwest and the still very steep dips are in general to the northeast, but the whole belt becomes narrow, and structural variations make it more difficult to decipher the stratigraphy. Across the little valley, and north of the Victorville-Barstow road, the quartzite-limestone reappears in a still narrower body with very steep dips mainly to the southwest, but the quartzites there contain considerable interbedded metavolcanic material.

In regard to the age of the Oro Grande metasediments, the above descriptions rather plainly indicate that it is distinctly younger than the Hinkley Valley complex. Hershey [22] found no fossils in his Oro Grande series, but suggested its correlation with the lower Cambrian of Inyo County. On Darton's 1915 map (sheet 24) the formation near Oro Grande is classed as pre-Tertiary. The finding of fossils by the writer, in at least two places, definitely shows the age of the Oro Grande metasediments to be late Paleozoic, and probably Mississippian. The fossils consist of crinoidal fragments, the best specimens of which were found

[22] Hershey, Oscar H., op. cit., p. 288, 1902.

in the limestone near the northern end of the area $3\frac{1}{4}$ miles northeast of Oro Grande, and in the conspicuous hill near the middle of the area $2\frac{2}{3}$ miles northeast of Victorville. The specimens were examined by Dr. Winifred Goldring of the New York State Museum, Dr. G. Arthur Cooper of the United States National Museum, and Dr. Edwin Kirk of the United States Geological Survey, all of whom agreed that they are of Carboniferous age, the specimens not being sufficiently well preserved for more accurate determination.

The limestone of the Oro Grande also looks much like the Furnace limestone in which poorly preserved fossils of Carboniferous (probably Mississippian) age have been found by Woodford and Harris [23] on the middle-northern slope of the San Bernardino Mountains.

Noble [24] has found Carboniferous crinoid stems in limestone in the eastern face of Ord Mountain about 12 miles southeast of Victorville. This limestone looks a good deal like the Oro Grande limestone.

Sidewinder Valley Metavolcanics

The name Sidewinder Valley metavolcanics has been given because of typical occurrences of these rocks in hills overlooking the northeastern end (or head) of Sidewinder Valley $3\frac{1}{2}$ to 5 miles northeast of Sidewinder Well. The metavolcanics include both original lavas and tuffs which have been much altered and more or less foliated. In most cases they are highly schistose.

In the type area, the eastern half of the small mountain just north and west of the Victorville-Barstow road consists entirely of schistose metavolcanics with a little interbedded quartz schist and quartzite. Highly altered lava-flows and beds of tuff are both represented. Volcanic bedding and foliation are essentially parallel and dip 70° to 80° to the southwest. These almost vertical metavolcanics run in great, conspicuous bands or beds right across the mountain, the more resistant beds forming bold, jagged lines of outcrops. The total thickness of the exposed volcanics is at least several thousand feet. The following descriptions of representative specimens will serve to make still clearer the nature of these volcanics. Two specimens are dark-gray, fine-grained, foliated, altered lavas. Under the microscope they show by volume percentages: oligoclase or acidic andesine, 15; quartz, 6-10; biotite, 2-10; magnetite, 4; epidote, 3; a little apatite; and groundmass too fine-grained for determination, 63. Both plagioclase and biotite individuals are often subhedral to euhedral, and they reach lengths of 1 to 3 millimeters. Many of the larger biotites have been altered to chlorite, magnetite, and epidote, leaving only ghost-like outlines of the original crystals, but there are also numerous tiny flakes. Most of the magnetite occurs as myriads of tiny grains. The holocrystalline, slightly porphyritic thin sections are foliated parallel to what seems to have been original magmatic flow structure. A specimen of light-gray, fine-grained, highly schistose lava has a mottled appearance caused by an irregular distribution of small, altered biotites which reach 2 millimeters in length. A section shows: oligoclase (much altered), 44; biotite, 3; magnetite, $2\frac{1}{2}$;

[23] Woodford, Alfred O., and Harris, T. F., Geology of Blackhawk Canyon, San Bernardino Mountains, California: Univ. California Dept. Geol. Sci. Bull. 17, p. 270, 1928.

[24] Noble, Levi F., Carnegie Inst. Wash. Yearbook, vol. 31, p. 356, 1932.

less than 1 percent each of epidote, zircon, hematite, and apatite; and groundmass too fine-grained for determination, 50. It is probably an altered andesite. A well-bedded, purplish, very schistose metatuff shows the foliation cross-cutting the bedding. It is fine- to finer medium-grained, with original fragmental texture well preserved. Under the microscope it shows: plagioclase (much altered andesine?), 20; quartz, 15; clinozoisite and epidote, 8; calcite 6; sericite, 5; magnetite, 2; fine-grained indeterminate groundmass, 44. Several other specimens are ash-gray to purplish, fine-grained, uniform, highly schistose metatuffs usually with relict fragmental texture. Five specimens are light bluish-gray, fine-grained, bedded, schistose metatuffs also with relict fragmental texture. Some interbedded metasediments are not easy to distinguish from the metatuffs in the field. One specimen is a light greenish-gray, very fine-grained, thin-bedded quartzite with tiny sand grains fairly well preserved. Several others are light-gray, fine-grained, uniform sericitic quartz schists which weather brown. About half of a thin section consists of rounded to subangular quartz grains, less than half a millimeter in diameter, together with numerous tiny sericite flakes, grains of pyrite usually altered to limonite, a little zircon and much very fine-grained groundmass which seems to be largely quartz.

The area, 2 miles in length, near Oro Grande consists of highly foliated metavolcanics with north-northeast strike and westward dip of 70°-80°, excepting in the north where the directions change so that the metavolcanics there dip under the Oro Grande metasediments. The steep-dipping, jagged, somber outcrops are conspicuous throughout the area. Victorville quartz monzonite cuts these metavolcanics sharply on the east, sending aplite and pegmatite dikes into them. The exposed thickness of the Sidewinder Valley metavolcanics is here probably not less than 2000 feet. Representative specimens are gray, fine-grained, highly schistose, biotitic, and usually rather uniform in composition, but with some suggestions of original bedding. Foliation and bedding always seem to be parallel. A thin section of the typical rock consists mainly of quartz, orthoclase, oligoclase, biotite, and less than 2 percent each of magnetite, clinozoisite, titanite, and zircon. It is highly schistose, holocrystalline, inequigranular, and in part too fine-grained for accurate determination. Another section is similar, but it contains sericite instead of the last three named accessory minerals. Both sections and specimens show relict fragmental textures of the original tuffs. Metalavas may be associated with the metatuffs, but, if so, they were not recognized as such.

The area of Sidewinder Valley metavolcanics between 2½ and 3½ miles northeast of Victorville contains both metatuffs and metalavas with the latter predominant. There are some interbedded Oro Grande metasediments. The metatuffs are much like the schistose types already described as occurring in the area near Oro Grande. A number of representative specimens, believed to be altered lavas, are gray to dark gray, fine-grained, somewhat foliated, and, in some cases, slightly porphyritic. They look like moderately altered andesites. Some of them may be altered sills. The thin section of one of the metatuffs is made up mostly of plagioclase, biotite, and orthoclase together with several percent of magnetite, and a little apatite and sericite. It is holocrystalline with a sugary texture, but much of it is too fine-grained for accurate determination. The metavolcanics of this area strike northward and dip very steeply to the

east, and so they rest conformably upon the adjacent Oro Grande crystalline limestone and Oro Grande-Sidewinder Valley mixed rocks.

From the above descriptions, it is evident that the Sidewinder Valley metavolcanics are closely associated with the Oro Grande metasediments, being in fact in part interbedded with them. They are, therefore, of the same general age as the late Paleozoic Oro Grande metasediments. They are much like the metavolcanics described by the writer [25] as occurring in the McCoy and the Coxcomb Mountains in eastern Riverside County. Gardner [26] has applied the name Ord Mountain group to certain igneous rocks which outcrop in the Newberry and Ord Mountains east of the Barstow quadrangle. That group includes (1) altered andesitic flows and tuffs, and (2) hypabyssal metaporphyry. He says there are associated slate beds derived from tuff, but he does not mention interbedded metasediments. The writer has not seen these metavolcanics, but they seem to be a good deal like the Sidewinder Valley metavolcanics, with which they may be correlative. In regard to the Ord Mountain group, Gardner (p. 270) says

"The possibility of a Paleozoic age can virtually be eliminated, for none of the Paleozoic sections in the surrounding regions show any indications of volcanic activity."

This statement no longer holds because the Sidewinder Valley metavolcanics are now known to be of late Paleozoic age.

Oro Grande and Sidewinder Valley Mixed Rocks

Mention has already been made of the fact that some Oro Grande metasediments occur in at least two of the areas mapped as Sidewinder Valley metavolcanics. These rocks are so notably mixed or interbedded in two small areas that they have been mapped separately. In the area between 2 and 3 miles northeast of Victorville, Sidewinder Valley metavolcanics and Oro Grande crystalline limestones, together with some mica schist, are so interbedded as to constitute a volcanic-sedimentary series. This belt of mixed rocks occupies a stratigraphic position intermediate between the Oro Grande limestones on the west and the Sidewinder Valley volcanics on the east, the mixed rocks striking northward and dipping very steeply to the east. Across the exposed thickness of hundreds of feet within the belt, there are a number of beds of altered lavas, some tuffs and possibly some sills, ranging in thickness from 1 to 50 feet. Some late Jurassic (?) aplite and pegmatite dikes cut the combination. The well-bedded limestone is usually much disturbed and contorted. A specimen of the metatuff is much like the metatuff in the area of metavolcanics a little to the east. In thin section it consists largely of orthoclase, acidic andesine, biotite, and hornblende, together with some quartz and magnetite, and very little apatite, zircon, and titanite. It is well foliated, holocrystalline, equigranular, and sugary in texture, but it is mostly too fine-grained for accurate determination of the minerals. A specimen of altered andesite or metadiorite from a sill is moderately foliated and inequigranular, varying from very fine-grained to finer medium-grained. About half of a thin section is too fine-grained for accurate determination, but it consists very largely of acidic andesine; considerable biotite and hornblende; some magnetite and clinozoisite; and a little titanite and apatite. The granoblastic groundmass contains a good many small phenocrysts of andesine.

[25] Miller, William J., op. cit., pp. 32-51, 1944.
[26] Gardner, Dion L., op. cit., pp. 266-270, 1940.

LATE JURASSIC? ROCKS

Quartz Diorite of Bell Mountain

The quartz diorite of Bell Mountain is well exposed 4 to 6 miles northeast of Victorville. In this area of about 2 square miles, the diorite is very largely gray, medium-grained, granitoid, and massive with some development of primary foliation, but there are many local variations, in grain size and composition. It is cut sharply by many granite, aplitic granite, and pegmatite dikes which are offshoots of the Victorville quartz monzonite. A specimen from near the road 4 miles east-northeast of Victorville is gray, massive, and mostly medium-grained with a few anhedral hornblendes $\frac{1}{2}$ to 1 centimeter in length. In thin section it shows by volume percentages: labradorite, 55; quartz, 15; hornblende, 12; biotite, 5; epidote, 5; muscovite and sericite, 3; magnetite, 2; microcline, 2; titanite, $\frac{3}{4}$; and little zircon and apatite. The original granitoid texture has been considerably modified by protoclastic granulation and deuteric action. Both hornblende and biotite are much altered to chlorite. The anhedral to euhedral labradorites are much altered to epidote and sericite. Another specimen from this locality is similar, but it contains less quartz, more plagioclase (andesine), less epidote, and no hornblende. Many tiny crevices are filled with late magmatic magnetite. Still another specimen from the same locality is dark gray, very massive, and fine-grained, with scattering plagioclase phenocrysts 1 to 2 millimeters in length. It shows in thin section: andesine, 50; quartz, 20; biotite, 8; augite, 6; microcline, 5; hornblende, 6; magnetite, $4\frac{1}{2}$; and some apatite and zircon. It is allotriomorphic, and it shows some protoclastic granulation. Specimens from the southern base of Bell Mountain are a little lighter gray, medium-grained, and very massive to slightly foliated. In composition they are much like those above described.

A number of dikes and sills of the quartz diorite cut the Oro Grande metasediments sharply in the southern and western parts of Sidewinder Mountain. The largest one, about $1\frac{1}{2}$ miles long and several hundred yards wide, varies from fine-grained along the contact to moderately coarse-grained. Megascopically and microscopically these diorite masses are very similar to the diorite of the type locality above described. All four thin sections examined show the plagioclase to be acidic adesine, and one section contains considerable microperthite. All are holocrystalline, inequigranular, somewhat porphyritic, and allotriomorphic. In all four sections the granular (protoclastic) groundmass is so fine-grained that it cannot be accurately determined. Deuteric alteration of minerals is very pronounced as shown by several percent each of sericite, epidote, and chlorite. Large and small dikes of similar diorite cut the crystalline limestone in the big quarry 6 miles a little east of north of Victorville, in the smaller quarry $3\frac{1}{2}$ miles northeast of Victorville, and on the hill $2\frac{1}{2}$ miles northeast of the same place. The diorite at the last-named locality is cut by Victorville quartz monzonite. The small mapped body of the diorite 5 miles east-northeast of Sidewinder Well cuts the Sidewinder Valley metavolcanics.

The Victorville quartz monzonite of the area between 3 and 4 miles a little north of east of Victorville has cut to pieces the quartz diorite, and contains many large and small xenoliths of it. Several of the larger xenoliths are arbitrarily represented on the accompanying geologic map

(Pl. V). Some were foliated by pressure of the intruding magma, which also variably injected the foliated rock, causing local development of mixed rocks, often crudely banded.

It is evident from the above descriptions that the quartz diorite is distinctly younger than the late Paleozoic Oro Grande metasediments and the Sidewinder Valley metavolcanics, and that it is older than the Victorville quartz monzonite of late Jurassic? age. It bears a relation to the Victorville quartz monzonite much like that of the Wilson diorite to the Lowe granodiorite in the San Gabriel Mountains, as described by the author (op. cit., pp. 62-63, 1934), and of the Sacatar quartz diorite to the Isabella granodiorite in the southern Sierra Nevada.[27] In all three of these regions the age of the diorite may be late Paleozoic to late Jurassic, probability favoring the late Jurassic age.

Gabbro-Diorite of Iron Mountain

Gabbro-diorite occurs in Iron Mountain in the southwestern part of the Barstow map area. From a distance of a mile or more, the numerous bold exposures within this 4-mile area present a very dark, somber appearance. In some places, particularly in the middle portion of the area, the gabbro-diorite is cut sharply and irregularly by numerous dikes of light-gray granite or quartz monzonite. No other area of this gabbro-diorite is represented within either the Barstow or the Victorville map area.

The gabbro-diorite of Iron Mountain shows many local variations in texture and composition, as do most basic rocks of this kind. The typical facies is tough, dark-gray, medium-grained, and very massive. A thin section of this rock from the north end of the area shows by volume percentages: andesine, 44; hornblende, 40; monoclinic pyroxene, 15; and magnetite, 1. The feldspar is often poikilitic because of numerous, tiny, anhedral to euhedral, light-green inclusions of hornblende. The hornblende shows light green—light bluish green—light greenish yellow pleochroism where fresh, but it has been considerably chloritized. The pyroxene is pleochroic from nearly colorless to light greenish gray. An original granitoid texture has been modified by localized granulation, particularly of hornblende.

Other common facies of the gabbro-diorite are medium- to very coarse-grained, dark-gray to gray, massive to slightly foliated, and often contain hornblende 1 to 2 centimeters in length. Such variations often occur within a few inches or a few feet.

The generally very massive gabbro-diorite is moderately foliated near the contact with the Hodge complex.

The gabbro-diorite of Iron Mountain is younger than both the Hinkley Valley and Hodge complexes, but no dikes of it were found cutting either of them. This gabbro-diorite may be of the same age as the quartz diorite of Bell Mountain, but it is distinctly more basic. Possibly the gabbro-diorite bears the same relation to the quartz diorite that the Summit gabbro does to the Sacatar quartz diorite of the southern Sierra Nevada.[28] If so, the gabbro-diorite of Iron Mountain is older—possibly a good deal older—than the quartz diorite of Bell Mountain, the latter being definitely older than the late Jurassic? Victorville quartz monzonite. The

[27] Miller, William J., and Webb, Robert W., Descriptive geology of the Kernville quadrangle, California: California Div. Mines Rept. 36, pp. 356, 358, 1940.
[28] Miller, William J., and Webb, Robert W., op. cit., p. 356, 1940.

gabbro-diorite may, then, be as old as late Paleozoic or as young as late Jurassic.

Victorville Quartz Monzonite

The name Victorville quartz monzonite has been given because of the many fine exposures of this rock in the two areas northeast and north of Victorville. A typical specimen from the second-named area, taken from a small quarry 4 miles a little east of north of Victorville, is light gray, medium-grained, biotitic, massive, and very uniform. It shows in thin section: orthoclase, 36; oligoclase-andesine, 34; quartz, 13; biotite, 9; microcline, 6; magnetite, 1; titanite, $\frac{3}{4}$; a little apatite and zircon. It is a typical quartz monzonite. Some of the plagioclase is zoned and euhedral. The biotite shows brownish green to light yellow pleochroism, and some of it is chloritized. The section has an equigranular, hypidiomorphic, normal, granitoid texture. A thin section of the rock from the southern part of the area is almost exactly the same. A specimen from the first-named area, taken from $1\frac{1}{2}$ miles north-northeast of Victorville, is also very similar in composition to the ones just described, but it shows some local granulation and several percent of magnetite. Nearly all minerals are fractured, and many of the tiny crevices are filled with magnetite.

A specimen from the area 2 to 3 miles southwest of the top of Bell Mountain is light gray, massive, with a fine to medium groundmass through which are irregularly scattered biotites 5 to 6 millimeters in diameter. A thin section contains: orthoclase, 35; oligoclase, 30; quartz, 24; microcline, 4; biotite, 5; magnetite, 1; titanite, $\frac{3}{4}$; and a little zircon and allanite. Pleochroism of the biotite is brownish green to light greenish yellow. About four-fifths of the section consists of fine-grained, highly granulated minerals through which are scattered relatively large, anhedral feldspar, quartz, and biotite individuals.. The rock is a quartz monzonite.

Much of the Victorville quartz monzonite, in the large area in the middle-northern part of the Victorville map area, is very light gray, massive, medium-grained, and almost devoid of dark minerals. Quartz monzonite, with the usual variations in grain size and content of dark minerals, constitutes the large bodies mapped in the middle-eastern and southeastern parts of the Victorville map area.

The quartz diorite of Bell Mountain is often cut irregularly by acidic dikes which no doubt are offshoots of the Victorville quartz monzonite. Good examples are large dikes in the middle-western part of the Bell Mountain area. A thin section of a specimen of the gray, medium-grained, massive, slightly porphyritic dike rock shows by volume percentages: microcline, 30; oligoclase, 30; quartz, 25; biotite, 9; leucoxene, $2\frac{1}{2}$; magnetite, $1\frac{1}{2}$; titanite, 1; hornblende, $\frac{1}{2}$; and small amounts of epidote, zircon, allanite, and apatite. About half the section is variably granulated, the quartz especially being very fine-grained. Some of the granulated material is in zones, probably a result of shearing. Leucoxene fills crevices in many places. Another specimen from the same exposure is similar in composition, but it is strongly foliated, nearly half the section is too fine-grained for accurate determination, and it contains about 15 percent of biotite in the form of myriads of tiny flakes in the finely granulated material. Hand specimens, which are very fine-grained, and dark gray, contain small, irregular, variably digested or assimilated more basic

rock which may be altered andesite of the Sidewinder Valley volcanics. A good example of aplitic granite from a dike cutting the diorite in the southern part of the Bell Mountain area is light gray, fine-grained, and massive, except for a faint banding which accentuates a primary foliation. In thin section it shows: orthoclase, 40; oligoclase, 24; quartz, 20; microcline, 10; biotite, 3; magnetite, 1½; sericite, 1; epidotite, ½; and very little titanite. Some phenocrysts of oligoclase are 1 to 3 millimeters in diameter.

Some satellitic granite, aplitic granite, and pegmatite dikes also cut the Victorville quartz monzonite. Most of them are of the usual kinds very low in mafic minerals. Special mention may be made of a medium- to moderately coarse-grained, light pinkish gray, massive granite from one of the dikes cutting the quartz monzonite 2 miles southwest of the top of Bell Mountain. A thin section of it contains: microcline, 60; quartz, 23; acidic oligoclase, 10; magnetite, 6; and biotite, 1. The whole section is badly crushed and fractured. The magnetite fills many cracks in, and crevices between, the mineral grains.

Large and small dikes of the Victorville quartz monzonite cut the Oro Grande metasediments as, for examples, on Quartzite Mountain and near the limestone quarry about 3½ miles northeast of Victorville. A specimen from the latter locality is gray and massive with a coarser medium-grained groundmass scattered through which are some anhedral feldspars ½ to 2 centimeters in length. A thin section shows: orthoclase, 35; oligoclase, 25; microperthite, 14; quartz, 10; hornblende, 8; microcline, 5; magnetite, 2; titanite, ½; and small amounts of apatite, zircon, and allanite. The orthoclase poikilitically incloses some quartz and plagioclase. Some oligoclase is zoned, and some is euhedral. Crevices are locally filled with magnetite. Locally, the granitoid texture has been partly destroyed by granulation between mineral grains.

The Victorville quartz monzonite is definitely younger than both the late Paleozoic Oro Grande metasediments and the quartz diorite of Bell Mountain. If the quartz diorite is of late Paleozoic age, then the Victorville monzonite may also possibly be late Paleozoic. It is highly probable, however, that the Victorville monzonite is of late Jurassic age. It is quite certainly a correlative of the Cactus granite which also cuts late Paleozoic strata in the northern part of the San Bernardino Mountains, and the nature of the rock and its relations to the country rocks are, in all important respects, like those of the Sierra Nevada batholith which is of late Jurassic age. It is also correlated with the Lowe granodiorite of the San Gabriel Mountains, the San Jacinto granodiorite, the White Tank quartz monzonite south of Twenty-nine Palms, and the White Tank monzonite northwest of Desert Center.

TERTIARY ROCKS

Quartz Latite Porphyry Dikes

Dikes in this category were observed by the writer in five widely separated localities within the Barstow and Victorville map areas. These dikes cut the country rocks very sharply, and they show steep dips. They reach as much as half a mile in length, and range in width from a few feet to 50 feet or more.

A system of nearly parallel quartz latite porphyry dikes occurs within an area of several square miles between 3 and 6 miles west-northwest of Barstow. Eleven of them are arbitrarily shown on the map

(Pl. VI), no attempt having been made to map individual dikes accurately. Probably more than eleven occur. In a number of cases the existence of the dikes is indicated only by surface fragments. A specimen from a typical dike cutting Hinkley Valley limestone, 4 miles west-northwest of Barstow, shows many anhedral to subhedral phenocrysts of andesine 1 to 2 millimeters in length, and some equally small quartz and chlorite individuals irregularly scattered through a fine-grained, greenish gray groundmass. It has a somewhat mottled appearance. A thin section shows by volume percentages: quartz, 35; orthoclase, 34; andesine, 20; chlorite (from biotite), 8; magnetite, 2; calcite, 1; and a little sericite. The andesine phenocrysts are usually strongly zoned, and both andesine and quartz phenocrysts are often much embayed by groundmass. The chlorite gives the greenish gray tint to the groundmass. Another specimen from the locality just mentioned is similar, but its groundmass is too fine-grained for accurate determination.

Several quartz latite porphyry dikes cut the Oro Grande limestone northeast of Oro Grande. Two are arbitrarily represented on the map (Pl. V). A thin section of one of these is very similar to the one above described, but it exhibits some foliation (probably primary) which is accentuated by wavy streaks of fine-grained biotite parallel to the structure. A specimen from another of these dikes is richer in biotite and strongly foliated.

One of the dikes cuts the gabbro-diorite of Iron Mountain sharply 3½ miles west-northwest of Hodge. It is gray, massive, and fine-grained, with almost glassy borders.

A massive, light greenish gray dike with many anhedral to subhedral phenocrysts of pinkish plagioclase 1 to 5 millimeters in length cuts the limestone sharply in one of the big limestone quarries 6 miles a little east of north of Victorville. No thin section of it was made, but it is, without much doubt, a quartz latite porphyry dike.

A number of roughly parallel quartz latite porphyry dikes form a system with a northwesterly trend in Sidewinder Mountain in the northwestern part of the Victorville map area (Pl. V). Most of them cut the Oro Grande metasediments, but one of them cuts diorite of Bell Mountain. A typical specimen from a dike in the southern part of the system is massive and light greenish gray with a very fine-grained groundmass through which are some irregularly scattered, subhedral to euhedral phenocrysts of quartz and feldspar 1 to 4 millimeters in length. A thin section shows: micrographic material (quartz and feldspar), 25; microcline, 20; quartz, 20; oligoclase-andesine, 14; epidote, 2½; titanite, 1½; biotite, 1½; sericite, 1½; magnetite, 1; a little zircon; and groundmass too fine-grained for determination, 13. Many phenocrysts of quartz and feldspar have been eaten into and embayed by micrographic material. One fissure, filled with fine granular epidote, extends across the section.

Quartz latite porphyry dikes much like those described have been found by the writer in several other parts of the desert region of southern California as for examples, in the Desert Center [29] and Needles-Goffs [30] regions. In both of those regions the dikes cut late Mesozoic granodiorite sharply, and they are, in turn, cut sharply by basic dikes. Fragments of

[29] Miller, William J., op. cit., pp. 65-66, 1944.
[30] Miller, William J., op. cit., pp. 121-122, 1944.

the quartz latite porphyry dikes were found in red sandstone and conglomerate of late Tertiary age 7 to 9 miles south of Needles. These dikes are, therefore, believed to be of Tertiary age, probably not later than middle Tertiary. It is also a significant fact that the quartz latite porphyry dikes of the Barstow and Victorville areas are, in general appearance and composition, a good deal like the Tertiary lavas of the same areas. They have not been observed cutting the lavas, and it is, therefore, possible that both the dikes and the lavas are of the same magmatic origin with the dikes forming feeding channels for the lavas. However, no positive field evidence for such a conclusion was found.

Volcanic Rocks

Three fairly large and a number of much smaller areas of Tertiary volcanic rocks are represented on the geologic maps of the Barstow and Victorville areas. The volcanics include both lavas and pyroclastics with the former predominating greatly. They range in composition from andesite to rhyolite. Pink, reddish brown, and gray colors prevail.

The largest area comprises Silver Mountain. A specimen typical of the northwestern part of that mountain, 5 miles northeast of Oro Grande, is pinkish gray and massive with a very fine-grained groundmass containing scattering feldspar and quartz phenocrysts less than 2 millimeters in length. A thin section shows by volume percentages: oligoclase, 23; quartz, 15; microperthite, 12; biotite, 5; calcite, 3; magnetite, 2; sericite, 10; and very fine-grained almost glassy, indeterminate groundmass, 30. Both quartz and microperthite have been considerably rounded and embayed by groundmass material. Both oligoclase and biotite have been much altered. The sericite occurs as myriads of widely scattered flakes, and in numerous veinlets in quartz and feldspar. The rock is a dacite porphyry or, possibly a quartz latite porphyry. In this vicinity, and also $1\frac{1}{2}$ miles farther south, the lava has been sufficiently kaolinized to warrant operation of kaolin mines. A specimen from the northeastern base of Silver Mountain is much like the one just described, but it is light greenish gray, and it contains no microperthite. A specimen from the southeastern foothills of Silver Mountain, $2\frac{1}{4}$ miles west-northwest of Sidewinder Well, is dark gray and massive with a fine-grained groundmass containing tiny scattered subhedral to euhedral oligoclase phenocrysts. In thin section it shows: quartz, 40; orthoclase, 36; oligoclase, 10; biotite, 6; magnetite, 3; epidote, $2\frac{1}{2}$; sericite, 2; and a little titanite and apatite. It is a rhyolite. A considerable body of highly altered tuff occurs in the middle-southern part of the Silver Mountain area. Within the Silver Mountain area the volcanics generally show rather steep dips and northwesterly strike, but there are many local variations.

The area of about 2 square miles of volcanics $3\frac{1}{2}$ to 5 miles east-northeast of Hinkley comprises crudely bedded lavas and coarse pyroclastics weathered to light gray, greenish gray, reddish brown, and yellowish brown. These volcanics, in the main mass of the mountain, have been folded into a synclinal structure trending northwestward, and with dips as high as 25°. A specimen of light brownish-gray lava from the southwestern front of the mountain has a very fine-grained groundmass which contains numerous anhedral to euhedral phenocrysts of andesine and quartz 1 to 3 millimeters in length. In thin section it shows: andesine (much altered), 15; quartz (much corroded), 12; biotite (lath-shaped),

9; magnetite (tiny grains), 2; calcite (secondary), 2; and very fine-grained, indeterminate groundmass, 60. A dacite is indicated by the determinable minerals.

The area of about 2 square miles of volcanics 3½ to 5 miles a little west of north of Barstow comprises mainly pinkish-gray and reddish-brown lavas and coarse pyroclastics. A specimen of the pinkish-gray rock from the southeastern part of the area has a good many subhedral to euhedral orthoclase phenocrysts 1 to 4 millimeters in length imbedded in a fine-grained to glassy groundmass. A thin section shows: orthoclase (much of it badly altered), 22; biotite (much of it altered), 4; calcite (secondary), 2; epidote? (many grains), 2; magnetite (numerous grains), 2; groundmass (fine-grained to glassy), 68. Most of the groundmass is glassy, but the grained portion seems to contain considerable plagioclase, and probably some tiny quartz grains. The unaltered portions of the phenocrysts are very fresh. The rock seems to be a hydrothermally altered rhyolite or quartz latite.

The volcanic rocks in the various smaller areas in the northeastern part of the Barstow map area, including those in and near Barstow, are very much like those of the two large areas just described.

The above-described volcanics in the Barstow and Victorville map areas are quite certainly Tertiary in age, and probably late Tertiary. Their nature, color variations, and mode of occurrence indicate strongly that they are correlative with the Pliocene Red Mountain andesite of the Randsburg area [31] and the Pliocene? Red Mountain andesite of the adjoining Newberry Mountains area.[32]

QUATERNARY DEPOSITS

Older Alluvium

The broad, low ridge, occupying about 14 square miles south and southwest of Barstow, has been mapped as older alluvium (Pl. VI). Considerable search failed to reveal any outcrops of bedrock within this area. It comprises poorly sorted, unconsolidated alluvial fan material which consists of angular to subangular rock fragments of all sizes to about a foot in diameter. The fragments include various types of crystalline rocks, particularly lavas. The whole ridge has been much dissected by erosion. The two smaller areas shown on the map east of Hodge consist of similar alluvial material. In all three areas the older alluvium rises distinctly above the general level of the adjacent younger alluvium. In the largest area the difference in altitude is as much as 500 feet. Apparently these areas of older alluvium represent erosional remnants of formerly much more extensive deposits.

Within the Victorville map area, the only important example of an older alluvial deposit noted by the writer forms a ridge north and northeast of Oro Grande along the north side of Quartzite Mountain. This ridge consists of poorly sorted angular to subangular rock fragments of all sizes to about a foot in diameter. This eastward-trending ridge is several hundred feet high, 2 miles long, and nearly a mile wide on the west. It is much dissected by erosion, and it is only a remnant of a once larger deposit. Possibly some other remnants of the older alluvium occur within the two map areas.

---

[31] Hulin, Carlton D., op. cit., pp. 42-46.
[32] Gardner, Dion L., op. cit., pp. 281, 283, 1940.

The older alluvial deposits are doubtless of Quaternary age, and, judging by the amount of erosion indicated by their dissection, they are probably not younger than middle Pleistocene.

Lake Beds

Deposits believed to be of lacustrine origin were found by the writer in three localities within the Barstow quadrangle. Most extensive is the outcrop of horizontal lake beds extending a mile or more northwest of Victorville and just west of the highway. The deposit, with an exposed thickness of about 100 feet, consists of well-bedded, light gray to nearly white clays, sandy clays, and limy material. The altitude of the top of the deposit is about 2800 feet. An excellent exposure about 50 feet thick shows at an altitude of 2500 feet in a marl pit 2½ miles west-northwest of Wild (or 1 mile southwest of the southwestern corner of the Barstow map area). It consists of horizontal marl beds 1 to 4 feet thick interbedded with clay beds 2 to 3 feet thick. Lake beds, similar to those just described, occur in a small area 3½ miles north-northeast of Oro Grande. Their altitude is about 3000 feet. Whether all of these lake beds represent deposition in a single large body of standing water, or in separate basins, was not determined by the writer. Lake beds of late Cenozoic (probably Quaternary) age have been described by Gardner [33] as occurring in the adjacent Newberry Mountains area. Some of these beds are mapped as extending into the very southeastern corner of the Barstow map area. According to Gardner, these lake beds are overlain by older alluvium. The relation between the lake beds and older alluvium in the Barstow quadrangle was not determined by the writer. All of the lake beds above mentioned may possibly be of the same age. In any case all are late Cenozoic, and probably Quaternary.

Younger Alluvium

The material in this category is widely distributed within both the Barstow and the Victorville map areas. It consists of various kinds of mantle-rock, principally alluvial fans and cones, together with some talus, river-bed deposits, and sand dunes. Alluvial fans and cones surround most of the mountains and hills of both areas, the fans often being several miles wide. Much of this alluvium is still in process of deposition. Several extensive alluviated surfaces are remarkably flat and little if any modified by stream erosion. Good examples are Hinkley Valley and Apple Valley, each of which covers 20 square miles or more. The smooth, gently sloping alluviated surface west of Victorville within the map area is only a small part of a surface which extends southwest and south many miles toward the San Gabriel and San Bernardino Mountains. In the Victorville area the alluvium reaches thicknesses of hundreds of feet. Thus in Apple Valley several wells penetrate the alluvium to depths varying from 300 feet to 722 feet; a well 1 mile south of Victorville reaches bedrock at 835 feet; and one just north of Victorville ends in alluvium at 200 feet. How much of this mantle-rock may be older alluvium is not known. In the Barstow map area there are no well records indicating such great thicknesses of the alluvium which, nevertheless, reaches depths of 100 feet or more.

[33] Gardner, Dion L., op. cit., pp. 289-290, 1940.

STRUCTURAL FEATURES

It seems probable that the area of the Barstow quadrangle, in common with most of southern California, was topographically in an old age or peneplain condition in very late Tertiary or early Quaternary time. Then block mountains developed through most of the quadrangle, particularly in its eastern two-thirds. None of these mountains rose more than a few thousand feet, most of them less than 2500 feet. Much of the fault activity ceased well before the close of the Pleistocene, since which time the mountain blocks have been much modified by erosion, sharply defined fault scarps have been obliterated, and alluvial cones and fans have spread over the intermont basins throughout most of the quadrangle. Most of the ridges and valleys of the quadrangle trend northwesterly thus indicating strongly that the principal faults also trend northwesterly. In all or nearly all cases, however, such faults within the Barstow and Victorville map areas are so effectually concealed under alluvium as to render unsatisfactory any attempt to locate them accurately on the maps. Mention may be made of a highly jointed belt of Victorville quartz monzonite $1\frac{1}{2}$ miles north of Sidewinder Well indicating a northwestward-trending fracture zone there. There is also some evidence of shorter faults with a northeasterly strike. In one place a conspicuous crush-zone, indicating such a fault, was observed. This is in the monzonite, a little east of the river 2 miles north-northwest of Victorville, where a once-thick mantle of alluvium has been stripped from the bedrock. There is evidence of some faulting in fairly late Quaternary time. Thus the broad ridge of older alluvium south of Barstow has been uplifted hundreds of feet, probably along the western extension of the late Pleistocene fault which the writer believes marks the northern base of Newberry Mountain.[34] The shape of this ridge also suggests strongly that it is a tilted block with a fault on its southwestern side. The ridge of older alluvium mentioned as occurring northeast of Oro Grande has also been uplifted, probably along a fault on the west. However, the faults are masked by younger alluvium.

The later Quaternary history was interrupted by the deposition of the smooth-surfaced alluvium over many square miles of the southwestern part of the Barstow quadrangle extending eastward to and a little beyond the present course of the Mojave River in the general vicinity of Victorville. This alluvium is part of the great fan which spread out northeastward and northward from the lofty San Gabriel and San Bernardino Mountains. These high mountains began their growth in early Quaternary time, but, unlike the much smaller mountains of the Barstow quadrangle, they have continued their growth to the present time. Alluvium from them has, therefore, completely buried the southwestern part of the Barstow quadrangle and encroached upon, and buried, spurs of the mountains near the Mojave River in the general vicinity of Victorville.

Across the Victorville map area the Mojave River has cut a narrow, well-defined valley about 200 feet deep into the alluvium, the cause of its entrenchment, according to Davis [35]

> "* * * being recent uplift, or, perhaps, a change in the regime of the river due to the capture of a considerable part of its headwaters, and the principal source of its detrital load in the San Bernardino Mountains, by Cajon Creek."

---

[34] Miller, William J., Recognition of faults in southern California: Jour. Geol., vol. 49, p. 95, 1941.

[35] Davis, William M., op. cit., p. 1350.

At two places in the Victorville map area, the Mojave River, during its down-cutting into the alluvium, encountered buried ridges of quartz monzonite into which the river was forced to cut very narrow gorges. Meantime the alluvial material has been removed by erosion from around the ends and tops of the buried bedrock, leaving the river in its seemingly anomalous courses through the narrow gorges, called Upper Narrows at Victorville, and Lower Narrows about halfway between Victorville and Oro Grande. These are, therefore, fine small-scale examples of a superimposed stream.

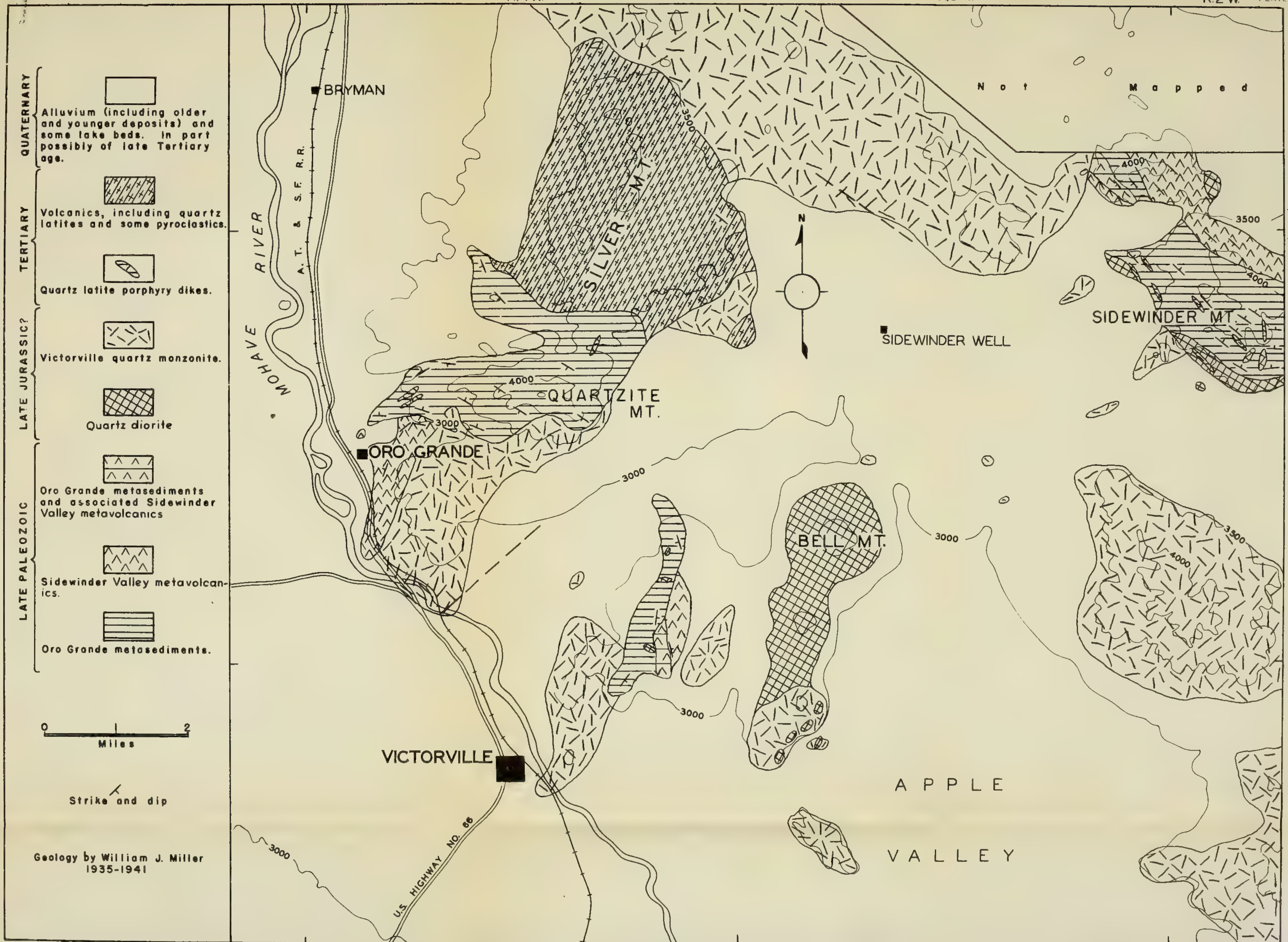
Interesting observations on the effects of sheetfloods and streamfloods on alluvial deposits and bedrock formerly buried under them, between Victorville and Oro Grande, have been published by Davis.[36] In his discussions, Davis calls the steep, rocky mountain east of Oro Grande ''Silver Mountain.'' In the present paper, it is called ''Quartzite Mountain'' following closely the designation ''Quartzite Peak'' given by Darton [37] in 1915. On the Barstow quadrangle of the United States Geological Survey, the name ''Silver Mountain'' is applied only to the broader, less sharply defined mountain mass north of Quartzite Mountain.

[36] Davis, William M., op. cit., pp. 1350-1353, 1358, 1381-1382, 1938.
[37] Darton, Nelson H., op. cit., sheet 24, 1915.

DIVISION OF MINES
WALTER W. BRADLEY STATE MINERALOGIST
OLAF P. JENKINS CHIEF GEOLOGIST

STATE OF CALIFORNIA
DEPARTMENT OF NATURAL RESOURCES

PLATE V



ACCOMPANYING STATE MINERALOGIST'S REPORT XL JANUARY 1944

R.4 W. R.3 W.

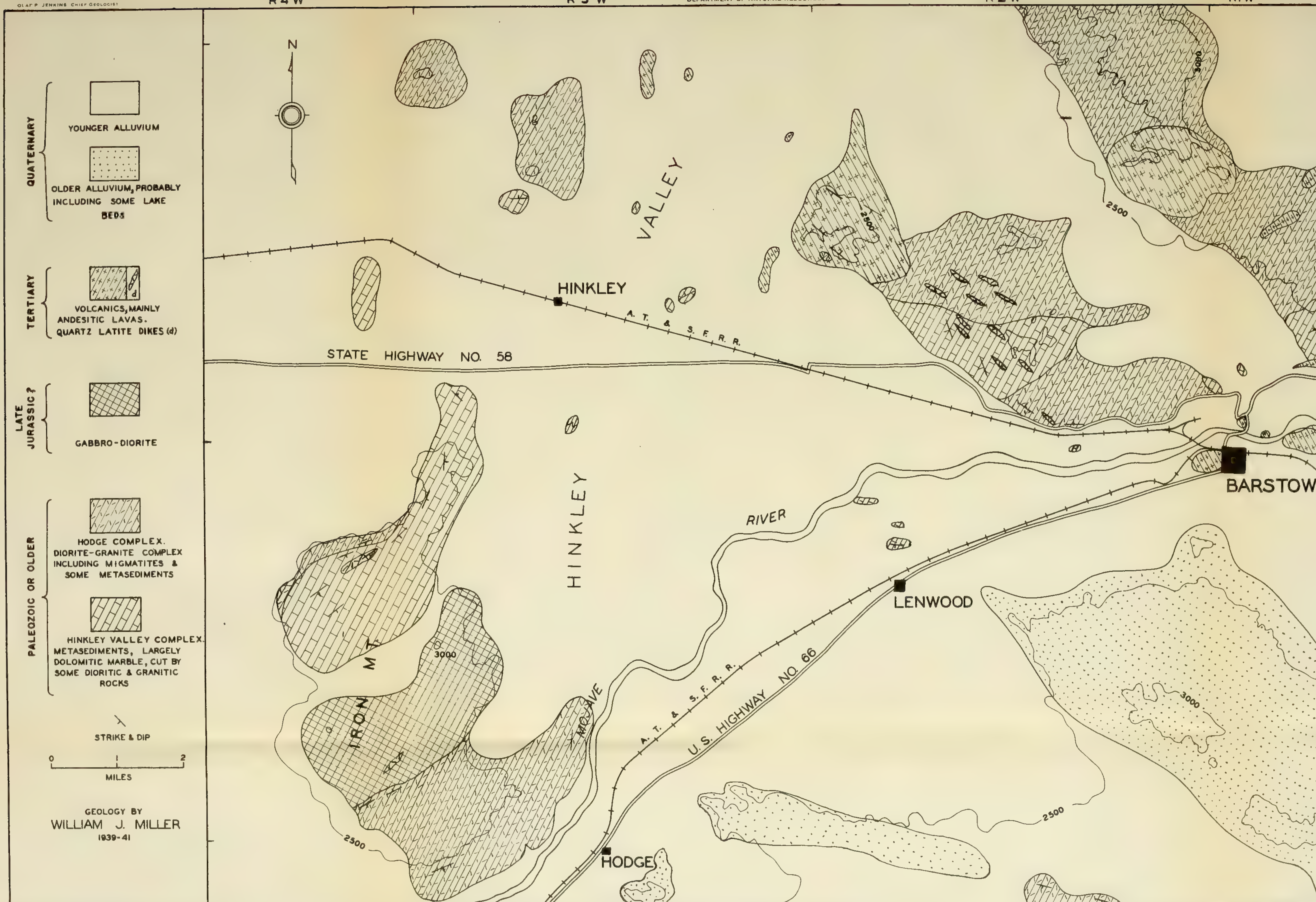
CONTOUR LINES FROM U. S. G. S. BARSTOW QUADRANGLE

GEOLOGIC MAP OF THE VICTORVILLE AREA, CALIFORNIA

DIVISION OF MINES
WALTER W. BRADLEY STATE MINERALOGIST
OLAF P. JENKINS CHIEF GEOLOGIST

STATE OF CALIFORNIA
DEPARTMENT OF NATURAL RESOURCES

PLATE VI



ACCOMPANYING STATE MINERALOGIST'S REPORT XL JANUARY 1944

GEOLOGIC MAP OF THE BARSTOW AREA, CALIFORNIA

CONTOUR LINES FROM U. S. G. S. BARSTOW QUADRANGLE

GEOLOGY OF THE NEEDLES-GOFFS REGION, SAN BERNARDINO COUNTY, CALIFORNIA

By WILLIAM J. MILLER *

OUTLINE OF REPORT

ABSTRACT

The Needles-Goffs region of about 650 square miles is in the extreme eastern part of the Mojave Desert of California. The Sacramento Mountains, and parts of the Dead Mountains, Mojave Mountains, Piute Mountains, and Homer Mountain, together with a group of intervening mountains, constitute the principal landscape features. Altitudes of 2500 to 3500 feet are common. The city of Needles lies near the middle-eastern border of the map area.

The oldest and by far most widespread rocks within the map area are early pre-Cambrian. These constitute a complex mainly of diorite and metadiorite, cut to pieces and often injected and migmatized or digested by granite. Some remnants of very old metasediments may also be present and granitized. This complex is called the Needles.

Next in age is a single small, narrow belt of crystalline limestone and quartzite bearing some poorly preserved fossil remains which suggest a late Paleozoic age.

Parts of several large intrusive bodies ranging from massive granodiorite to quartz monzonite, and several small ones, come next in order of geologic age, being probably late Mesozoic, or possibly early Tertiary. These intrusive masses cut sharply through the Needles complex.

Tertiary rocks comprise hypabyssal and volcanic rocks, and nonmarine sediments. These are, in order of age: quartz latite porphyry dikes, basic dikes, rhyolite porphyry dikes, red sandstones and conglomerates, and volcanics.

* Professor of Geology, University of California at Los Angeles. Manuscript submitted for publication June 24, 1943.

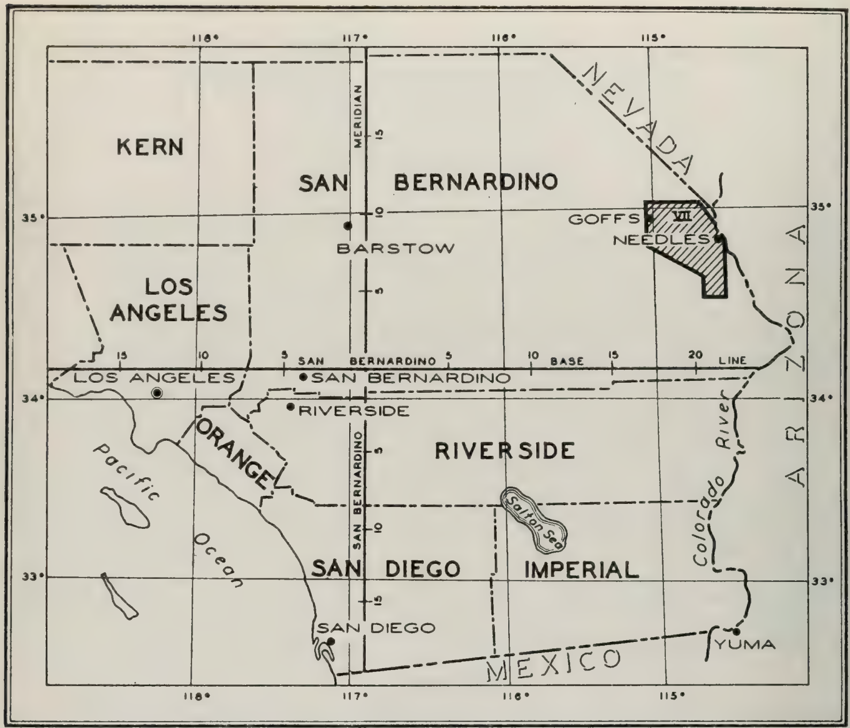


FIG. 1. Index map showing location of Needles-Goffs region.

Remnants of early Quaternary basaltic lava flows occur as conspicuous caps on four small mountain peaks. Both older and younger Quaternary alluvium are extensive, concealing the bedrock of about half the map area. The younger alluvium is still being deposited over large areas.

The foliated, sedimentary, and volcanic rocks of all ages except the Quaternary are tilted at various angles, their dips ranging from 15° to 40°. At one locality the volcanics show an anticlinal structure.

A prominent northward-trending normal fault, called the Dead Mountain fault, bounds the Dead and the Sacramento Mountains on the west. A less conspicuous fault marks the eastern base of the Sacramento Mountains.

INTRODUCTION

The accompanying geologic map of the Needles-Goffs region is based upon field work carried on by the writer mainly at intervals during the winters of 1938, 1939, and 1940 as part of a program of study of the crystalline rocks of southern California. Part of the cost of field and laboratory work was covered by grants in aid from the Board of Research of the University of California, Los Angeles. This aid is gratefully acknowledged.

The only important previous publication on the geology of the region is that by N. H. Darton [1] who, in 1915, published a small-scale

[1] Darton, N. H., Guidebook of the western United States, Part C, The Santa Fe route: U. S. Geol. Survey, Bull. 613, pp. 146-148 and Sheet 21, 1915.

geologic map, and described briefly some of the important rock formations. All of the plutonic, dike, and metamorphic rocks, with the exception of a little limestone, are mapped together as ''granite and schist.''

In 1929, D. G. Thompson[2] published some very brief remarks on the rocks of the Needles-Goffs region, but added nothing to the earlier work of Darton.

The geologic map that accompanies this present report is a complete revision of the corresponding part of the Geologic Map of California (1938) which was compiled from various sources.

GEOGRAPHIC AND RELIEF FEATURES

The Needles-Goffs region, described in this report, covers an area of about 650 square miles in the extreme eastern part of the Mojave Desert of San Bernardino County. The city of Needles, with a population of several thousand, lies near the middle-eastern border of the region, and Goffs, a small railroad community, lies near its middle-western border. The Santa Fe Railroad crosses the region from Goffs to Needles. U. S. Highway 66 also crosses the region from west to east and through Needles.

The base map used for the geologic field work was part of one of the topographic sheets prepared by The Metropolitan Water District of Southern California. Contour lines on the accompanying geologic map were taken from that sheet. The eastern part of the Needles-Goffs map area lies within the Needles quadrangle published by the United States Geological Survey.

Approximately half the map area is mountainous or hilly with numerous outcrops of bedrock; in the other half of the area, however, Quaternary alluvium completely covers the bedrock.

The principal mountains are in the eastern part of the map area. Of these, the southern part of the Dead Mountains (maximum altitude 3500 feet) lie in the northeast; the Sacramento Mountains (maximum altitude 3200 feet) in the middle east; and the western side of the Mojave Mountains (maximum altitude 3500) in the southeast. All of these mountains are topographically rugged, representing a late youthful or early mature stage in the desert cycle of erosion. A well-defined, narrow, relatively low pass separates the Dead Mountains from the Sacramento Mountains, and a less well-defined, much broader, relatively higher pass separates the Sacramento Mountains from the Mojave Mountains. Everywhere from the eastern base of these mountains at an altitude of about 1200 feet, a conspicuous alluvial slope 3 to 6 miles wide extends downward to the Colorado River at an altitude of about 450 feet. The Sacramento and the Dead Mountains each have a relatively steep western front and longer, less steep eastern slopes.

The mountains lying west of the Sacramento Mountains, and in the middle and middle-southern parts of the map area, are less rugged and generally less imposing because they do not rise so high above the surrounding country, but a number of points reach altitudes of about 3500 feet. A similar description applies to the northern extension of the Piute Mountains in the western part of the map area, and Homer Mountain in

[2] Thompson, D. G., The Mohave Desert region of California: U. S. Geol. Survey Water-Supply Paper 578, p. 719, 1929.

the northwestern part. The last three named mountain masses are separated by extensive, gently sloping, alluvial (so-called "wash") deposits. This large western part of the Needles-Goffs map area is, therefore, in a late mature or early old age stage in the desert cycle of erosion.

PRE-CAMBRIAN ROCKS

Needles Complex

There are excellent outcrops of the Needles complex in the northwestern Mojave Mountains, and along and west of the highway between 10 and 17 miles south of Needles. It comprises a mixed lot of crystalline rocks, the components of which are usually too intimately associated to permit them to be mapped separately. It is an igneous-metamorphic complex, by far the most extensive within the map area.

The chief constituents of the Needles complex are diorite varying to metadiorite and more or less crudely foliated granite varying to granodiorite. The older dioritic rocks have been so thoroughly cut to pieces by the distinctly younger granitic rocks that only numerous irregular-shaped remnants of the older rocks remain, the latter usually ranging from less than a foot to several hundred feet in length. Thus the two rocks form a patchwork with dioritic material predominating in some places, and granitic material in others. This is well exhibited in the type area south of Needles where much of the diorite is medium- to fine-grained, massive to crudely foliated, little granitized or granite-soaked. A thin section of this rock shows by volume percentages: andesine, 57; hornblende, 37; biotite, $1\frac{1}{2}$; magnetite, $1\frac{1}{2}$; titanite, $1\frac{1}{2}$; and apatite, $\frac{1}{2}$. The andesine is variably zoned. Pleochroism of the hornblende is bluish green to light greenish yellow, and of the biotite dark greenish brown to yellow. Titanite occurs as several relatively large crystals. The dark-gray medium-grained rock has a hypidiomorphic granitoid texture. Much of the diorite, however, is more strongly foliated, and it has been granite-soaked and locally injected lit-par-lit, so that migmatites and crudely banded gneisses result. The granite is light gray, medium-grained, crudely foliated, and impure because of assimilation of dioritic material. There seems to be no well-defined structural trend of foliation in the type area.

The Sacramento Mountains west and southwest of Needles consist of the Needles complex. In general the rocks are like those of the above-described type area; but gray fine- to medium-grained massive to distinctly foliated granitic material predominates over dioritic material. A thin section of granitic material from this region shows the composition of a granodiorite. It contains by volume percentages: quartz, 30; oligoclase, 37; orthoclase, 28; biotite, $2\frac{1}{2}$; muscovite, $1\frac{1}{2}$; magnetite, $\frac{3}{4}$; a little apatite and zircon. Much of the quartz is granulated and sheared. The biotite, with brownish-green to light-yellow pleochroism, is irregularly distributed as large and small individuals, often strung out between the quartz and feldspar grains. Both biotites and muscovites are usually bent. There is much granulation, especially between the mineral grains. The section is holocrystalline, inequigranular, and crudely foliated, and suture texture is common. It is notably sheared and altered plutonic rock. Numerous dioritic and metadioritic xenoliths show every stage of assimilation by the granite magma. Locally, considerable amounts of strongly foliated metadiorite have been injected lit-par-lit by granite, producing crudely banded gneisses. These are well exhibited 5 miles

west of Needles. The foliation shows a general northwesterly strike and dips 30° to 40° SW.

The Needles complex constituting the southern portion of the Dead Mountains is much like that of the Sacramento Mountains. Crudely banded lit-par-lit injection gneisses are, however, more common, an excellent display being in the mountain side near Klinefelter. A thin section of altered (granite-soaked) diorite from the southern tip of the mountains shows by volume percentages: oligoclase, 52; quartz, 25; biotite partly altered to chlorite, 16; sericite, 5; calcite, 1; magnetite, $\frac{3}{4}$; and a little apatite, zircon, and allanite. Most of the medium-sized quartz grains are broken, sheared, and finely crushed. The oligoclase forms microaugens, with crushed and corroded borders, and with sheared quartz and micaceous minerals curving between the augen parallel to the shear. The strongly foliated rock is holocrystalline, inequigranular, much granulated, and blastoporphyritic. Variably foliated fine-grained dark-gray amphibolitic rocks occur locally in the Dead Mountains. These are probably metadiorite but they may in part represent basic metavolcanic rocks. The banded gneiss may contain locally some highly altered metasediment. Some small pegmatitic granite dikes cut the mixed rocks. Foliation strike is in general northerly, and the westerly dips are rather steep.

In the group of small mountains (sometimes called Ibis Mountains) for several miles around South Pass, the Needles complex consists very largely of dioritic gneiss varying locally to rather massive diorite cut irregularly by relatively small amounts of granite. Banded gneiss is very subordinate. There seems to be no clear structural trend of foliation.

The Needles complex in the Piute Mountains, between Goffs and Highway 66, is exceptional in that it is practically all dioritic gneiss. This important component, covering some 10 or 12 square miles, could here be mapped separately.

A facies of the Needles complex of special interest is a porphyritic gneiss which constitutes nearly all of the pre-Tertiary bedrock of Homer Mountain and vicinity, and the Piute Mountains from Highway 66 south for some distance. Here and there relatively small amounts of altered dioritic and impure granitic rocks are closely associated with the gneiss. The typical porphyritic gneiss, exposed in road cuts along Highway 66 in the vicinity of Mountain Spring, is a dark pinkish-gray, crudely foliated, variably coarse-grained, porphyritic rock. The moderately coarse-grained groundmass consists of much biotite in the form of myriads of tiny flakes, among which are distributed irregularly many feldspar, and fewer quartz grains. The subhedral to anhedral feldspars range in size from less than a millimeter to about 4 centimeters. The quartz grains, which are less than a centimeter in length, are very irregular in shape and little granulated or crushed. Most of the smaller feldspars are acidic plagioclase and they are strongly granulated; but the larger ones, which are pinkish potash feldspars, show little or no crushing. The scattered large feldspars give the rock a porphyritic appearance. The texture is not, however, that of a typical plutonic rock. It lacks uniformity in composition, degree of foliation, and size and distribution of phenocrysts. Somewhat similar rocks have been found by the writer in various parts of southern California, good examples being in the Maria Mountains north of Blythe, in the Old Woman Mountains between Essex and

Chubbuck, in the Marble Mountains along Highway 66 north of Cadiz, in the Bristol Mountains a few miles east of Amboy (where porphyritic gneiss cuts highly crystalline bedded marble and quartzite), and in the Pinto Mountains near Twenty-nine Palms. Observations in these and other places have led the writer to conclude that attack of granite magma upon dioritic rock produced a syntectic magma from which the peculiar porphyritic gneisses crystallized somewhat in a manner suggested for the porphyry near Twenty-nine Palms.[3] The porphyritic gneiss of the present report is probably the Fenner gneiss mentioned by Hazzard and Dosch [4] as occurring near Mountain Spring, and in the Old Woman Mountains, but no descriptive details are given by them.

Mention should be made of a facies of the Needles complex different from any already described. This occurs along and near Highway 66 about 7 miles southwest of Mountain Spring and west of the Needles-Goffs map area. The exposures show a good deal of metasedimentary material, including quartzitic and schistose rocks with bedding fairly well preserved, and closely associated basic, altered, igneous material. These rocks have been injected lit-par-lit by granite, and have been affected by granitization or digestion, so that banded rocks and migmatites have resulted. These rocks are in nearly all respects like the writer's typical San Gabriel formation of Los Angeles County.[5] This banded gneiss, rich in metasediments, may belong with the Essex series described very briefly by Hazzard and Dosch [6] as occurring in the southern Piute Mountains and in the northern Old Woman Mountains.

The Needles complex is for the most part less conspicuously banded than the Pinto gneiss near Twenty-nine Palms [7] and the San Gabriel formation of Los Angeles County.[8] This is probably in part because usually there was little metasediment associated with the diorite, and in part because the diorite was not so much foliated, at the time of intrusion of the granite magma. But probably more important was the less fluid nature of the granite magma as indicated by the relative scarcity of pegmatitic facies. Thus the conditions in the Needles-Goffs region were less favorable for injection lit-par-lit than in the San Gabriel and Pinto Mountains.

The known original components of the Needles complex, in order of age, are: metasediments, diorite and metadiorite, and granite, the porphyritic gneiss being probably a granite-diorite syntectic, and the banded gneisses being granite-injected diorite (or metadiorite) and metasediment, or both. In view of the fact that, within the Needles-Goffs map area, these components are usually so variably, and often so intimately, associated as to preclude mapping them separately, they have been mapped together as the Needles complex. All of these rocks, and combinations of them, are quite certainly early pre-Cambrian in age, as are similar rocks in other parts of southern California. Positive evidence is lacking within the map area, but not far west of it Cambrian strata rest by profound unconformity upon rocks which without any doubt are to

[3] Miller, William J., Pre-Cambrian and associated rocks near Twenty-nine Palms, California: Geol. Soc. America Bull., vol. 49, pp. 433-435, 1938.
[4] Hazzard, John C., and Dosch, Earl F., Archean rocks in the Piute and Old Woman Mountains, San Bernardino County, California: Geol. Soc. America Bull., Proc. 1936, p. 309, 1937.
[5] Miller, William J., Geology of the western San Gabriel Mountains of California: Univ. California at Los Angeles Pub. Math. and Phys. Sci., vol. 1, pp. 49-55, 1934.
[6] Hazzard, John C. and Dosch, Earl F., op. cit., p. 309, 1937.
[7] Miller, William J., op. cit., pp. 424-428, 1938.
[8] Miller, William J., op. cit., pp. 49-55, 1934.

be classed with the Needles complex. Such localities are in the Marble Mountains north of Cadiz,[9] and in the Old Woman Mountains 6 miles southeast of Fenner.[10] Rocks of late pre-Cambrian age in the southern half of California and in Arizona are petrologically very different from the Needles complex, consisting mainly of metasediments, usually either unaltered or only moderately metamorphosed, and not extensively cut to pieces or intimately injected with granitic rocks.

PALEOZOIC ROCKS—METASEDIMENTS

A small valley lies just west of the northern and higher part of the Sacramento Mountains. A nearly straight, bold escarpment several hundred feet high forms the western boundary of this valley for 3 miles. A long narrow strip of moderately metamorphosed limestone, arenaceous limestone, and quartzite, mostly 100 to 150 feet thick, outcrops persistently in the basal portion of the escarpment, as shown on the geologic map. Most of the limestone is very fine-grained crystalline and light brownish gray, but some of it is bluish gray on the weathered surface. The fairly well-preserved bedding shows a west-southwesterly dip of 30° to 40°. Tertiary volcanic rocks with a like dip constitute the upper portion of the escarpment. Rocks similar to the Tertiary volcanics dip under the limestone at and near the base of the escarpment. Some small sills of the igneous rocks cut the limestone. Out in the valley a number of small masses of the limestone occur within the volcanics. Several outcrops of the Needles complex also occur on the valley floor. These relationships are rather puzzling, but probably the limestone, resting by unconformity upon a somewhat irreguar floor of the Needles complex, was in part overflowed, and in part cut sill-like, by the spreading and upwelling magma.

A feature of particular importance about this limestone is the presence in it of what are almost certainly fossil remains. Darton shows this occurrence of limestone on his map [11] and says that it contains "at one point fossils that are probably Carboniferous," but no description of the fossils is given. A hand specimen of the bluish-gray limestone collected by the writer has fossils in the form of a dozen tubes, an inch or less in length and an eighth of an inch in diameter, filled with siliceous material. These are roughly parallel, but separate, and stand at right angles to the bedding. They may represent a form of columnar corals.

On the alluvial slope covered with coarse debris, a few miles southwest of Needles, there are scattered fragments of light brownish-gray and bluish-gray, very fine-grained, moderately metamorphosed limestone much like that above described. A collected specimen contains some irregularly distributed slender columns as much as an inch long and replaced with chalcedony. There are also many cross-sections of such columns. They may represent replaced crinoidal remains. The fact that these limestone fragments have been washed down the slope from the west suggests that such limestone may occur in, or along the base of, the Sacramento Mountains southwest of Needles. The writer did not locate it.

[9] Darton, N. H., op. cit., p. 152, 1915.
[10] Hazzard, John C., and Dosch, Earl F., op. cit., p. 309, 1937.
[11] Darton, N. H., op. cit., p. 147, 1915.

Limestone similar to that of the Needles-Goffs region, and containing some rather poorly preserved fossils of Paleozoic (probably Mississippian) age, has been seen by the writer in various parts of southern California, near Baker, near Victorville, and on the north side of the San Bernardino Mountains.

LATE MESOZOIC (?) ROCKS—GRANODIORITE

Five areas of gray, massive, medium-grained granodiorite varying to quartz monzonite are shown on the accompanying geologic map. Throughout this area the rock is massive and rather uniform. Two representative specimens were collected for special study. One of these is a coarse-medium-grained, massive, and pale pinkish-gray granodiorite containing small scattered biotites. A microscopic section shows by volume percentages: oligoclase, 45; quartz, 28; microcline, 22; biotite, $3\frac{1}{2}$; magnetite, 1; and small amounts of titanite, epidote, muscovite, zircon, and apatite. It has a typical granitoid texture. The quartz shows wavy extinction. The other specimen is much the same megascopically, but it is light gray and slightly porphyritic. It is also similar microscopically, but microperthite and oligocase in about equal amounts comprise 50 percent of the section. A little myrmekite was noted. The oligoclase individuals vary from anhedral to euhedral. This rock is a quartz monzonite. In the field these rocks contain few aplite dikes and very few silexite dikes.

Granodiorite, varying to quartz monzonite, much like that just described, occurs in the Needles-Goffs map area in a large body in the Dead Mountains, and in smaller bodies at the following localities: 3 miles north of Goffs; 1 mile south-southeast of Goffs; and 5 to 6 miles south-southeast of Goffs. The granodiorite in these five areas looks much like the White Tank quartz monzonite in the Twenty-nine Palms region,[12] but it does not weather into huge rounded joint blocks and boulders probably because it is usually highly fractured.

The granodiorite in the northwestern corner of the map area forms part of a much larger body whose full extent was not determined. This rock is much like that of the above described Mojave Mountains area, but it is distinctly porphyritic. Scattered through the massive, light-gray, coarse-medium-grained matrix there are pinkish subhedral to anhedral phenocrysts of potash feldspar some of which are more than 2 centimeters in length. The rock is cut by some fine-grained aplitic granite dikes and by still younger basaltic and rhyolitic dikes. The rock looks much like the typical porphyritic Lowe granodiorite of the San Gabriel Mountains.[13] A thin section of the typical granodiorite from 6 miles north of Goffs contains the following volume percentages of minerals: quartz, 44, oligoclase, 28; microperthite, 4; microcline, 20; muscovite, 1; biotite, $\frac{3}{4}$; magnetite, $\frac{1}{2}$; and still less epidote, zircon, titanite, and apatite. The matrix is inequigranular and slightly granulated. The oligoclase crystals are anhedral to euhedral, and the quartz shows wavy extinction.

Five of the mapped bodies of granodiorite show sharp intrusive contacts against the Needles complex. Such contacts, in the Mojave Mountains and in the Dead Mountains, are plainly visible from a distance of several miles. Perhaps the most striking is in the Piute Mountains, 6

[12] Miller, William J., op. cit., pp. 438-439, 1938.
[13] Miller, William J., op. cit., pp. 41-42, 1934.

miles southeast of Goffs, where the light-gray granodiorite contact against dark-gray diorite-gneiss is strikingly shown in the side of the small mountain just north of Highway 66. Some granodiorite dikes extend upward abruptly into the diorite of the upper part of the mountain. There are aplite and silexite dikes in the granodiorite. In the Homer Mountain area, the granodiorite sharply cuts the porphyritic gneiss of the Needles complex. In all cases observed by the writer, the granodiorite has had practically no metamorphic effect upon the older rocks.

Definite age determination of the granodiorite in the Needles-Goffs map area cannot be made. It is certainly much younger than the pre-Cambrian rocks, and older than the quartz latite porphyry, basic, and rhyolite porphyry dikes, as well as the volcanic-sedimentary rocks which are quite certainly of Tertiary age. In all important respects the massive, non-metamorphosed granodiorite, varying to quartz monzonite, is like similar rocks definitely known to cut late Paleozoic, and even early Mesozoic, rocks in various parts of southern California. Within the Needles-Goffs area, the granodiorite is not in contact with the small showing of later Paleozoic strata, but, not far west of the area similar granodiorite cuts late Paleozoic strata in the Marble Mountains and Triassic (?) rocks in the Old Dad Mountains. The granodiorite is doubtless post-Paleozoic in age, and it is either late Mesozoic (probably late Jurassic) or possibly early Tertiary. The eastern part of the Homer Mountain area is pre-Cambrian porphyritic gneiss. In the western part of the same area (north of Goffs), the writer on careful examination found that the main body of rock, 5 or 6 square miles in extent, is the already described massive, medium-coarse-grained, porphyritic granodiorite cut sharply by aplitic basaltic, and rhyolite porphyry dikes. The large rhyolite porphyry dikes are distinctly more resistant to the weather than the main mass of granodiorite country rock. These dikes form conspicuous outcrops, and numerous large and small fragments of them are widely scattered over the area. It would, therefore, be easy to conclude that the rhyolite dike material (probably Tertiary) forms the main body of country rock; actually, however, the main body is porphyritic granodiorite (probably late Mesozoic). Northwestward from the granodiorite body here mentioned to Silver Lake, there are several small batholiths of similar rock shown as Tertiary on the Geologic Map of California (1938). The writer has seen something of these occurrences, but failed to find proof of their Tertiary age. Can it be that rhyolite porphyry or granitic dikes or sills cutting Tertiary rocks have led to the conclusion that these batholiths are also of Tertiary age as in the Ivanpah region where Hewett [14] reports a quartz monzonite sill of Laramide age? Finally, the possibility of an early Tertiary age of these granodiorite batholiths must be conceded. Tertiary intrusives in small bodies are known in various parts of the Cordilleran region.

TERTIARY ROCKS

Quartz Latite Porphyry Dikes

A group of quartz latite porphyry dikes is shown on the geologic map in the southwestern part of the Mojave Mountains. Most of them

[14] Hewett, Donnel F., Tertiary history of the Ivanpah region, southeastern California: Geol. Soc. America Bull., vol. 50, p. 1951, 1939.

occur in the granodiorite, but a few are in the adjacent Needles complex. These dikes cut through the country rocks very sharply and they show steep dips. They form a crude, roughly parallel system with a general north-northwesterly trend. They reach more than half a mile in length, and in width range from a few feet to 50 feet. On the geologic map they are rather arbitrarily represented, no attempt having been made to delimit them in detail. A specimen of the common rock shows numerous subhedral to euhedral white oligoclase phenocrysts, ranging to 5 millimeters in length, some small quartz grains, and smaller chlorites irregularly scattered through a fine-grained, greenish-gray groundmass. It has a somewhat mottled appearance. A thin section shows by volume percentages: oligoclase, 30; orthoclase (in groundmass), 20; quartz (in groundmass), 15; epidote, 4; chlorite, 3; magnetite, $1\frac{1}{2}$; calcite, 1; a little sericite and apatite; and more or less indeterminate very fine-grained groundmass, 25. Some oligoclase has zonal growths. The epidote, most of the chlorite, and the calcite are alteration products of hornblende of which only euhedral crystal outlines or ''ghosts'' now remain. Some chlorite may have come from biotite (now not shown). The chlorite gives a slight greenish tint to the rock. The microcrystalline groundmass of uncertain composition is probably nearly all quartz and orthoclase. Another specimen is megascopically and microscopically similar, but the oligoclase phenocrysts are smaller, and there are scattered, elongate, partly unaltered biotites.

A very striking exhibition of quartz latite porphyry dikes is in the hills west and southwest of South Pass, plainly visible from Highway 66. The dikes form a parallel system with a west-northwest strike. They are rather arbitrarily represented on the geologic map. Megascopically and microscopically these dikes are much like those above described as occurring in the southwestern Mojave Mountains, but a thin section shows the plagioclase to be acidic andesine, and largely chloritized biotite to be more abundant (8 percent). A little pyrite also is present, and its oxidation probably causes the dark-brown surfaces of the dikes.

A third group of the quartz latite porphyry dikes, trending nearly due north, occurs in the southern part of the Sacramento Mountains. A number of them are rather arbitrarily represented on the geologic map, and others probably occur in this vicinity. One of these dikes (in Monumental Canyon) is well foliated as a result of shearing. Under the microscope it is seen to be holocrystalline, blastoporphyritic, and granulated. The foliation is accentuated by crude bands of biotite, some of which curve around the acidic andesine phenocrysts. Possibly the shearing was associated with fault movements along the base of the mountains in this vicinity.

Quartz latite porphyry dikes much like those of the Needles-Goffs map area have been found by the writer in several other parts of the desert region of southern California, as, for example, in the Desert Center area. In both areas just mentioned these dikes cut late Mesozoic granodiorite sharply, and are in turn cut sharply by basic dikes. Fragments of the quartz latite porphyry have been observed in the red sandstone and conglomerate of late Tertiary age 7 to 9 miles south of Needles. The quartz latite porphyry dikes are believed, therefore, to be of early or middle Tertiary age.

Basic Dikes

Many of these fine-grained massive medium-gray basic dikes occur within the map area. No microscopic examination was made, but they are no doubt andesitic or basaltic in composition as is true of similar dikes seen by the writer in many other parts of southern California. They always cut the country rocks very sharply. On the accompanying geologic map most or all of them occur in three general areas—the southwestern Mojave Mountains, the eastern Sacramento Mountains, and the Homer Mountain area. The dikes are rather formally represented on the map, no attempt having been made to map them individually. Some others probably occur elsewhere. The dikes reach a width of 50 or 60 feet, and a length of half a mile or more.

In the southwestern Mojave Mountains the mapped portion of the granodiorite is everywhere cut irregularly by numerous basic dikes which form a wide-spaced, crude network; but most of them follow a great northwestward-trending joint system in the granodiorite. Some of the dikes of this group also cut the adjacent Needles complex. In a few cases these basic dikes cut sharply through quartz latite porphyry dikes.

The basic dikes of the other two groups are very similar to those just described, but several of those in the Homer Mountain area are cut sharply by rhyolite porphyry dikes.

None of the basic dikes of the map area have been found cutting either the volcanics or the red sandstones of later Tertiary age, but fragments of the dike rocks occur in the sandstone 7 to 9 miles south of Needles. The additional fact that they cut the late Mesozoic (or early Tertiary) granodiorite, and the still later quartz latite porphyry dikes, indicates that the basic dikes are of early or middle Tertiary age.

Rhyolite Porphyry Dikes

A rather remarkable system of rhyolite porphyry dikes occurs in the Homer Mountain area north and northeast of Goffs. The geologic map gives a good idea of their general distribution. This system of roughly parallel dikes trends nearly due east. The dikes are rather formally shown on the map, no attempt having been made to map them individually or to scale. Both the porphyritic gneiss facies of the Needles complex and the late Mesozoic (?) granodiorite are cut sharply by the dikes. In several cases these dikes cut sharply through the basic dikes. Some of the dikes are as much as three-quarters of a mile in length and 75 feet in width. They are plainly visible over the nearly barren hills.

Megascopically, the typical rhyolite porphyry dike rock from 8 miles north-northeast of Goffs shows a light-gray, massive, fine-grained groundmass through which are scattered phenocrysts of flesh-colored anhedral to subhedral orthoclase 2 to 15 millimeters in length; anhedral to euhedral phenocrysts of plagioclase 2 to 10 millimeters in length; some rounded phenocrysts of quartz of similar size; and a few elongate, subhedral to euhedral decomposed biotites. Because of chilling of the magma, the dike borders, particularly the phenocrysts, are finer grained.

Careful study of a thin section of the typical dike rock from 8 miles north-northeast of Goffs shows the following minerals by volume percentages: myrmekite (orthoclase and quartz), 24; quartz, 18; orthoclase, 15; acidic oligoclase, 15; altered biotite, 3; magnetite, 3; calcite, 1; titanite, $\frac{1}{2}$; smaller amounts of zircon, apatite, epidote, and sericite; and

very fine-grained groundmass (probably quartz and feldspars), 20. The feldspars and quartz are mostly in the form of phenocrysts 2 to 8 millimeters in length, the feldspars being the larger in hand specimens. Some of the feldspars are subhedral to euhedral, but usually their edges have been corroded. Most of the plagioclase is badly decomposed. The quartz phenocrysts are mostly rounded by corrosion, and deeply embayed locally with groundmass. In some cases tiny veinlets of groundmass cut into and through quartz individuals. At least half of the fine-grained groundmass consists of many small myrmekite grains, and the rest is too fine-grained for certain determination, but it is probably all, or nearly all, quartz and feldspar. The biotites are almost completely decomposed leaving only ghost remnants and some chlorite. The relatively large magnetite grains probably crystallized early in the magma, but the myriads of very tiny grains are of late origin, in some cases forming veinlet filling.

Another specimen from a dike in the same vicinity, about 8 miles north-northeast of Goffs, is similar to the rock just described, but the flesh-colored orthoclase phenocrysts are smaller, and the groundmass is somewhat darker gray, probably because there are more chloritized biotites. In thin section some of the groundmass is exceedingly fine-grained and indeterminable. Border portions of the dikes are in general still finer grained.

Rhyolite porphyry dikes similar to those just described have been observed by the writer west of the Needles-Goffs map area about 6 miles east-southeast of Mitchell's Caverns where they intrude early pre-Cambrian rocks. A thin section contains some microperthite and a good deal of microcline, partly as phenocrysts, but no myrmekite. There are some acidic oligoclase phenocrysts, but the quartz and orthoclase all occur in the fine-grained wholly determinable groundmass. Otherwise this dike rock is very much like that already described from 8 miles north-northeast of Goffs.

The rhyolite porphyry dikes are doubtless of Tertiary age, but probably not late Tertiary. In the Homer Mountain area, north and northeast of Goffs, several of the numerous basic dikes are cut through sharply by the rhyolite porphyry dikes which are, therefore, definitely the younger. The age relation of the rhyolitic dikes to the later Tertiary volcanic and sedimentary rocks of the Needles-Goffs map area is not known. Similar dikes above mentioned as cutting the pre-Cambrian rocks east and southeast of Mitchell's Caverns, were not seen cutting the extensive late Tertiary volcanics which overlie the pre-Cambrian on the north; however, no extensive search was made. Near Goodsprings, Nevada, about 60 miles north-northwest of the rhyolite porphyry dikes of the present report, Hewett [15] describes sills and dikes of granite porphyry so associated with thrust faults as to indicate their late Cretaceous or early Tertiary age, probably the latter. Judging from his meager description, Hewett's granite porphyry dikes are much like the writer's rhyolite porphyry dikes, and possibly they are of the same age. All evidence known to the writer indicates an early or middle Tertiary age of the rhyolite porphyry dikes in the northeastern part of the Needles-Goffs map area.

---

[15] Hewett, Donnel F., Geology and ore deposits of the Goodsprings quadrangle, Nevada: U. S. Geol. Survey Prof. Paper 162, pp. 37-38, 1931.

Red Sandstone and Conglomerate

Red sandstone and conglomerate occupy an area of about 2½ square miles from 7 to 9 miles south of Needles. They lie upon the Needles complex, a broad tongue of which extends well into the area of sediments, as shown on the geologic map. The rocks are mostly dark red coarse sandstone, conglomerate, and conglomeratic sandstone. There are many angular to subangular fragments, representing facies of the Needles complex, some of which are a foot or more in diameter. There are also some fragments of the quartz latite porphyry dikes and basic dikes, but no fragments of the late Tertiary volcanics were found. The dike fragments are comparatively little weathered. The rocks are crudely bedded with a general dip of about 35° SW. The exposed thickness of the formation is many hundreds of feet.

The red color, crude bedding, and unweathered nature of the constituent fragments clearly indicate the continental origin of the formation. Its relation to the Needles complex, and the rather uniformly strong southwest dip, suggest that the formation was deposited, probably as alluvial fan material, upon a sloping, irregular surface of the gneiss, and subsequently strongly tilted and downfaulted against the base of the Sacramento Mountains.

Two miles northwest of the area just described, are two very small areas of the red conglomeratic sandstone. These are exposed remnants of a once larger mass. In both the dip is about 15° SW. One of the masses is downfaulted sharply against the Needles complex of the Sacramento Mountains.

The age of the formation is quite certainly later Tertiary (Miocene or Pliocene). Darton [16] maps it as early Quaternary and younger than the volcanic rocks next to be described. Its degree of consolidation, its strongly tilted structure, the absence of fragments of the volcanic rocks in it, the manner in which it is down-faulted at the base of the mountains, and the amount of erosion which has occurred since its deposition all point to an age greater than Quaternary.

Volcanic Rocks

Three fairly large and three very small areas of volcanic rocks are shown on the geologic map. These are only erosional remnants of more extensive areas. Several square miles in the Sawtooth Range in the southeastern corner of the map area consist of these volcanics. They are lava-flows with some volcanic agglomerates. These rocks have been sculptured by erosion and weathering into many small, jagged, picturesque peaks. A typical specimen is a pinkish-gray rock with an aphanitic groundmass through which are irregularly distributed numerous subhedral to euhedral nearly white plagioclase phenocrysts 2 to 8 millimeters in length. A thin section shows volume percentages of minerals as follows: basic oligoclase phenocrysts, 45; biotite (much altered), 5½; magnetite, 2; a little zircon and hematite; and very fine-grained or glassy, indeterminate groundmass, 47. This rock is, therefore, andesite porphyry. Other specimens from this locality are very fine-grained and dark gray or light brownish-gray. Some flow structure shows. These volcanics show a general dip of about 25° SW.

[16] Darton, N. H., op. cit., sheet 21, 1915.

In the largest area of the volcanics, just west of the northern part of the Sacramento Mountains, there are mainly andesitic lava flows with some associated volcanic breccias. A few small sills cut the strip of limestone which extends through the area. Either side of the limestone strip, the volcanics dip 30° WSW, and, east of this near the base of the Sacramento Mountains, the dip is 30° ENE, indicating a well-defined anticline in this part of the area.

A typical specimen of the lava from the escarpment just above the limestone is a light brownish-gray, massive rock with a very fine-grained matrix through which are scattered some phenocrysts of anhedral to euhedral plagioclase 2 to 5 millimeters in length. There are also some tiny biotites visible megascopically. Under the microscope this rock is seen to contain by volume percentages: oligoclase-albite, 15; biotite (badly decomposed), 6; magnetite (both original and secondary), $3\frac{1}{2}$; quartz, 2; apatite, $\frac{1}{2}$; calcite, $\frac{1}{2}$; hematite, $\frac{1}{2}$; and very fine-grained groundmass, 72. The few small quartz phenocrysts have been eaten into and embayed by groundmass material. The groundmass is holocrystalline, but microcrystalline. It is largely indeterminate, but there seems to be a good deal of plagioclase. This rock may well be classed as an andesite porphyry. Other lavas from this area are probably somewhat more basic and somewhat more acidic than andesite. The other four areas of volcanics are very similar to those of the two large areas just described.

The age of the volcanics is, without much doubt, middle or late Tertiary, possibly late Miocene. Volcanics of this age occur in many parts of southern California. The tilted and folded structures of the volcanics, the manner in which they are down-faulted against the Needles complex of the Sacramento Mountains, and the amount of erosion which has affected them, all strongly point to a pre-Quaternary age. In the Sawtooth Range adjacent quartz latite porphyry dikes and basic dikes do not penetrate the volcanics, proving the latter to be the younger.

Interbedded Sandstones and Volcanics

The combination of sandstones and volcanics is presumed to represent interbedding of the red conglomeratic sandstone and the volcanics, both of which have been described. It may occupy a geologic position between the red sandstone-conglomerate formation and the volcanics. In any case the main masses of the sandstone-conglomerate formation are believed to be older than the main masses of the volcanics, because fragments of the volcanics were not seen in the sediments. The following is suggested as a reasonable interpretation of events. First, deposition of sandstone and conglomerate; second, continued deposition of the sediments with some interbedding of volcanics; and third, piling up of the volcanics with little or no associated sediments. Or, possibly vulcanism and sedimentation occurred at about the same time, but in different places.

Fine exposures of the sedimentary-volcanic combination occur in the Klinefelter area. The most interesting outcrops are in the vicinity of Klinefelter where crudely bedded red conglomeratic sandstone and several intercalated beds of volcanics are sharply downfaulted against the Needles complex of the Dead Mountains. One volcanic bed, 25 to 30

feet thick, is mainly agglomerate associated with some porous lava. Another is mainly porous lava containing many irregularly distributed strips of the sandstone in the form of inclusions. Microscopic study of the volcanics was not made, but they seem to be basaltic or andesitic. Just north of Klinefelter the actual fault surface, dipping vertically, is visible for some distance. At and close to the fault the sandstone beds, including one lava flow, stand in nearly vertical position. Westward the dip diminishes rapidly, becoming nearly horizontal within a quarter of a mile. This is an updrag structure produced during the faulting. Outcrops of interbedded sandstone and volcanics also occur in other parts of the Klinefelter area in which the conglomeratic sandstone predominates.

Several much smaller areas of associated sandstone and volcanics are shown on the geologic map. In the largest of these, 5 miles south-southwest of Needles, red conglomerate dips at 20° under similarly dipping beds of lava flows and volcanic breccia. One mile southwest of this, more rocks of the same kind are faulted sharply against the Needles complex.

QUATERNARY ROCKS

Lava Caps

At four localities within the Needles-Goffs map area, sharply defined hills or small mountain peaks are capped with nearly black basaltic lava. These lava caps reach several hundred feet in thickness. All of these were noted by Darton [17] who, in regard to the two near Goffs, says:

> "Half a mile southeast of Goffs, at the foot of the main mountain mass, there is a conspicuous butte capped by black lava (basalt). Two miles south of the station there is a high peak, known as Black Top, just west of the main mountain slope. Its tabular top is due to a thick sheet of lava (basalt) which lies on a thick deposit of sand and granite boulders that are underlain by the coarse granite of the main mountain slope."

This lava-capped peak, with talus from the black lava covering its steep slopes, is a conspicuous feature of the landscape. In regard to Signal Peak, 7½ miles north-northeast of Goffs, Darton says it

> "is capped by black lava (basalt) similar in relations to the lava caps south of Goffs and of the same age."

The fourth occurrence is described by him as follows:

> "Six miles southwest of Klinefelter is the high, conspicuous Tabletop Mountain, consisting of a cap of basalt on a mass of tuff and agglomerate."

This occurrence is different from the others in that the basalt rests unconformably upon the distinctly older (Tertiary) volcanics.

Perhaps the most significant thing about these lava caps is that they are mere erosional remnants of once more or less extensive basaltic lava flows which poured out long before the present topographic features of the Needles-Goffs area existed. As general erosion of the area proceeded, these hard, resistant lava remnants protected the immediately underlying rocks from being cut down as rapidly as would otherwise have been the case. Thus the lava-capped peaks are explained.

The basaltic lavas are certainly a good deal younger than the Tertiary sedimentary-volcanic rocks already described. They cannot be younger than earlier Quaternary as proved by the rather profound

[17] Darton, N. H., op. cit., pp. 147-148, 1915.

erosion of the region since they poured out. They are, therefore, of earlier Quaternary, or possibly very late Tertiary, age.

Alluvium

Quaternary alluvium occupies large parts of the Needles-Goffs map area. This practically unconsolidated material is more than 800 feet thick in some places, and absent in others, as proved by wells drilled along the line of the railroad. Thicknesses of several hundred feet are doubtless common. The alluvium is a heterogeneous lot of material comprising angular, subangular, and fairly well-rounded rock fragments ranging in size from more than a foot in diameter to fine silt. When it is realized that all of this great quantity of alluvium has been, and still is being, derived from the surrounding mountains, it becomes evident that really profound erosion and deposition have taken place within the map area.

The long, wide apron extending down to the Colorado River, from the Dead and the Sacramento Mountains, consists of somewhat older alluvium. This is shown by the fact that it has for some time been trenched and partly removed by the many wet-weather streams coursing across it from the mountains. Only very locally is there any present-day deposition.

The extensive alluviated surfaces west of the Dead and the Sacramento Mountains are younger Quaternary; widespread deposition is still going on.

STRUCTURAL FEATURES

Faults

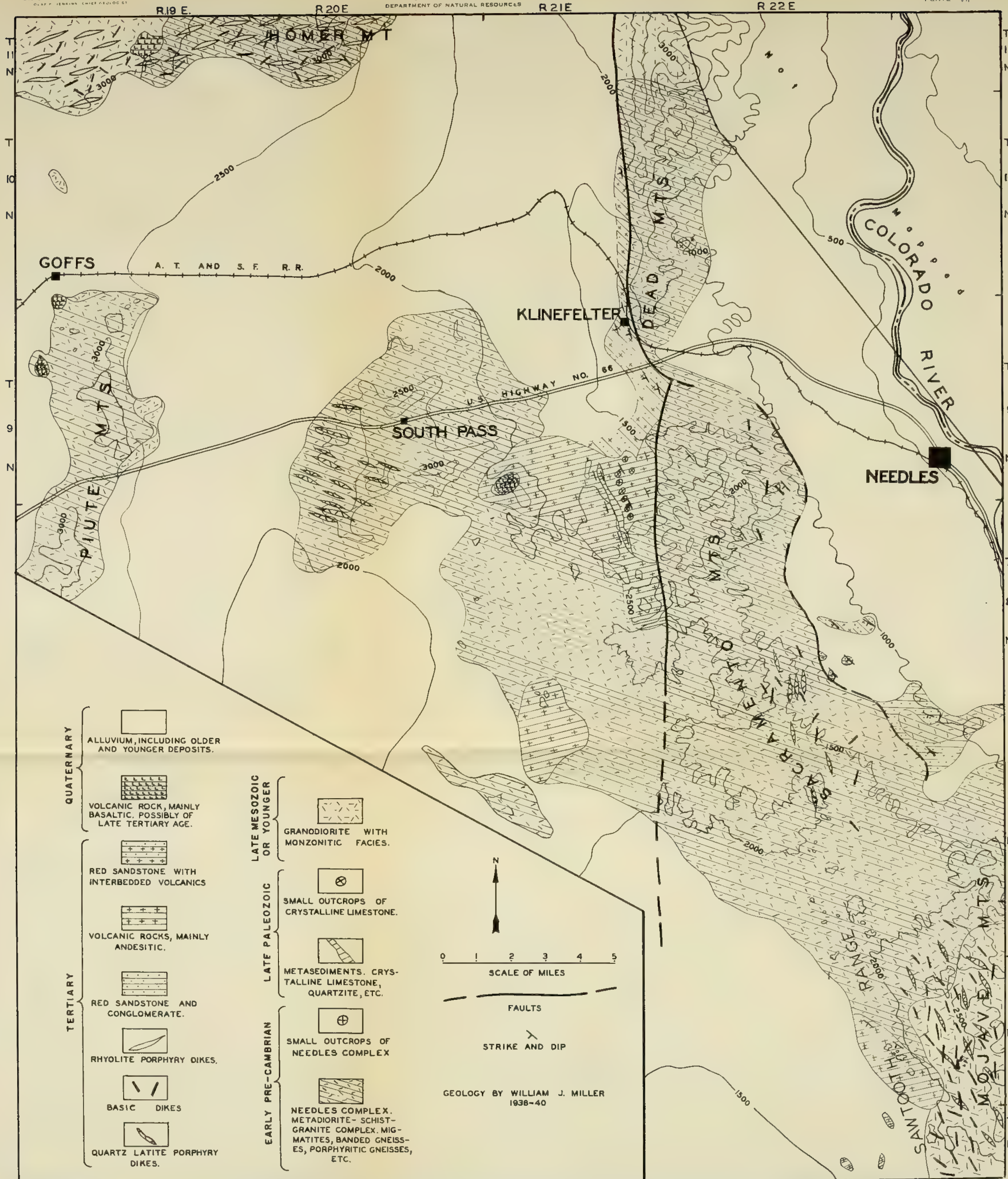
The name Dead Mountain fault is here proposed for the most important fault within the Needles-Goffs map area. It forms the western boundary of the Dead and the Sacramento Mountains, striking north. It is very clearly traceable for more than 20 miles, almost all the way across the map area. However, it is lost under the alluvium in the south. Northward, beyond the map area, it extends at least a number of miles more. The downthrow side is plainly on the west, as proved by the red sandstones and volcanics coming against the crystalline rocks along the fault for many miles on the west side. The fault surface is vertical, or nearly so, being actually visible at a number of places, as just north of Klinefelter where the red conglomeratic sandstone and interbedded volcanics are in direct contact with the Needles complex. At and near the contact there, the sandstone beds are upturned almost vertically while adjacent to the fault on the other side, the Needles complex is badly crushed in a zone 10 to 20 feet wide. At several places, between 5 and 10 miles south of Klinefelter, the volcanics come practically against the Needles complex along the fault, which there is also nearly vertical. The maximum vertical displacement along the fault is not known, but it is at least 1000 feet. Both the Dead and Sacramento Mountains are tilted, much eroded block mountains with steep slopes on the western (fault) sides and less steep downslopes to the east.

There is good evidence that a fault (or fault zone) also bounds the Sacramento Mountains on the east. Thus at several places south-southwest of Needles, as already mentioned, the red conglomeratic sandstones and associated volcanics are down-faulted sharply against the Needles

DIVISION OF MINES
WALTER W. BRADLEY, STATE MINERALOGIST
OLAF P. JENKINS, CHIEF GEOLOGIST

STATE OF CALIFORNIA
DEPARTMENT OF NATURAL RESOURCES

PLATE VI



ACCOMPANYING STATE MINERALOGIST'S REPORT XL, JANUARY 1944 **GEOLOGIC MAP OF THE NEEDLES-GOFFS REGION, CALIFORNIA** CONTOUR LINES FROM MAP BY THE METROPOLITAN WATER DISTRICT OF SOUTHERN CALIFORNIA

complex. At several other places along the base of the mountains, particularly west of Needles, the crystalline rocks are strongly jointed and more or less crushed in zones parallel to the mountain base.

A similar fault may extend along the eastern base of the Dead Mountains, but sufficient positive evidence was not found to justify the mapping of a fault there.

Excessive jointing, forming a wide belt striking north-northwest in the southwestern Mojave Mountains, suggests nearness to a fault (or fault zone) there. Some evidence of minor faults was noted in other places, but these faults were not worked out by the writer.

Tilting, Folding, and Jointing

The foliated, sedimentary, and volcanic rocks of all ages, excepting the Quaternary, are more or less strongly tilted, often dipping from 15° to 40°. Some details have been given in the discussions of the various formations.

The anticlinal fold in the volcanics west of the northern part of the Sacramento Mountains, and the upturned strata along the fault just north of Klinefelter, have already been described. Otherwise any fold structures are absent or difficult to be sure about.

Rock jointing of the usual kind is of course common throughout the area. More than the usual amount of faulting often occurs in belts or zones near the large faults.

SPECIAL ARTICLES

AIROX CONCRETE AGGREGATE

By S. G. Dolman*

The Airox Company is an organization which makes a light aggregate for concrete by burning diatomaceous shale suitable for this purpose. Officers of the company are A. P. Pratt, president, E. M. Markell, general manager, D. A. Sanford, plant superintendent, and R. L. Harsin, plant chemist and foreman. The head office is at 307 West Eighth Street, Los Angeles.

The plant is located on a diatomaceous shale deposit about 2 miles north of Casmalia, a small town on the Southern Pacific Railroad in Santa Barbara County, California.

The deposit is a portion of the Sisquoc formation, a local name for lower to middle Pliocene sediments. It is a diatomaceous mudstone containing hydrocarbons in varying amounts. When the plant was first put in operation, only that portion of the deposit impregnated with oil was used. The company is now experimenting with material which contains little or no oil but carries sufficient hydrocarbons in other forms to fulfill the requirements of the process.

The raw material is drilled by jackhammers and blasted with dynamite. It is then loaded by power shovel into trucks which transfer the material to crushers where it is sized and stored in feed bunkers. Three sizes of aggregate are made: $\frac{3}{4}$-inch, $\frac{1}{2}$-inch, and sand. From the feed bunkers, the material is fed into steel rotary kilns, of which there are two, each 125 feet long and 7 feet in diameter, placed in tandem. Number one kiln is used for driving off and burning the excess oil out of the material. Vesiculation of the material is mostly accomplished in kiln number two.

The material passes from number one to number two kiln where a temperature of 2300 degrees Fahrenheit is maintained. This temperature is sufficient to cause incipient fusion on the surface of each pellet which seals the porous interior of the aggregate. To prevent clinkering of the pellets, they are dusted with silica powder before entering kiln number two. When the material emerges from the second kiln, it is conveyed to bins for cooling and shipment.

The plant has a capacity at present of about 150 cubic yards per day. If it is found that the quality of the aggregate can be maintained by using material free from oil, both kilns will be used to gasify the carbonaceous material and fuse the surface of the pellets in one operation, thereby increasing the capacity of the plant.

---

* Deputy Oil and Gas Supervisor, Division of Oil and Gas, Santa Maria, California. Manuscript submitted for publication May 22, 1944.

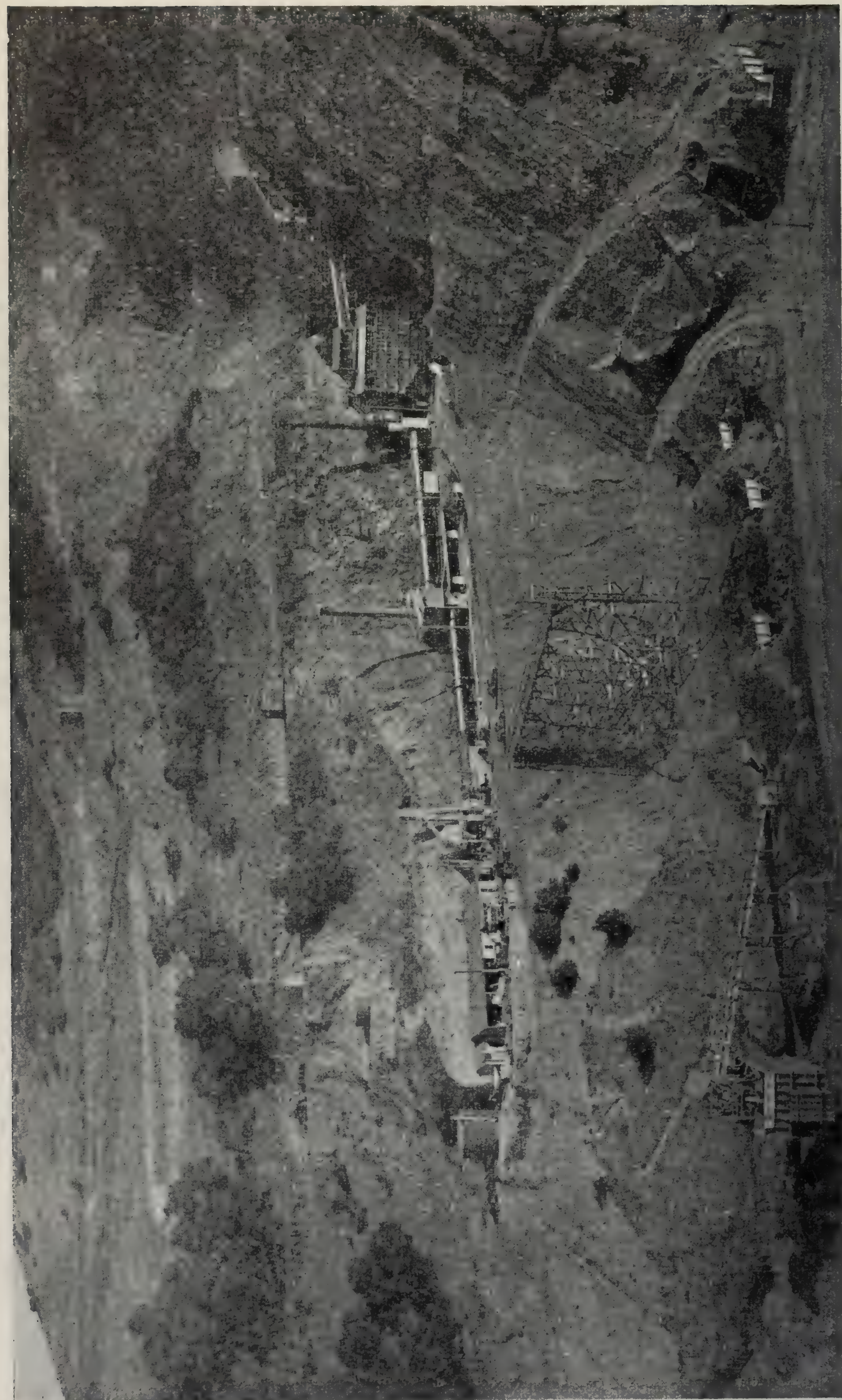


FIG. 1. Airox plant near Casmalia, Santa Barbara County. *Photo by courtesy of Airox Company.*

In short, the process consists of making a sized aggregate which is vesiculated by the expansion of gases generated within the material by heat and is then sealed by fusing the surface of each pellet.

Concrete made with this aggregate is claimed to have one and one-half times the compressive strength of ordinary concrete, while its weight is about 60 percent of the ordinary product.

Concrete made with Airox aggregate is used in constructing barges for the transportation of oil. The machinery and equipment were furnished by Defense Plant Corporation, a governmental agency, but the operations are not under the supervision of the Government.

MARKETING MAGNESITE AND ALLIED PRODUCTS [1]

By Charles L. Harness [2] and Nan C. Jensen [3]

CONTENTS

INTRODUCTION

Magnesia (MgO) has a variety of uses, and it has become increasingly important as a war material because of the imperative demand for refractories to line metallurgical furnaces, and because magnesia is used to make the light metal, mangesium, now employed in aircraft and other implements of warfare. Magnesia occurs as an integral part of nearly 60 minerals, but it is extracted commercially from only a small number of them. The present commercial sources are magnesite, brucite, dolomite, raw sea water, sea-water bitterns, and well brines.

MAGNESIA RAW MATERIALS

Magnesite, magnesium carbonate, $MgCO_3$, theoretically contains 47.8 percent MgO and 52.2 percent CO_2. There are two varieties of magnesite, crystalline and cryptocrystalline (dense or amorphous). The latter type, though not so plentiful as the former, is generally purer. It resembles unglazed white pottery in texture, whereas the crystalline variety is generally dark and granular, though the color may vary. The

[1] Reprinted in part from U. S. Bureau of Mines Information Circular 7269, December, 1943. Tables 5, 6, 7, *Imports*, omitted.

Acknowledgment is made to Alvin Schallis, a former member of the staff, for liberal use in this report of material that he had compiled.

[2] Assistant mineral economist, Nonmetal Economics Division, Bureau of Mines.

[3] Nonmetal Economics Division, Bureau of Mines.

principal domestic deposits of crystalline magnesite are near Chewelah, Stevens County, Wash. (which has supplied most of the magnesite mined in the United States), in the Gabbs Valley area of Nevada (near Luning); and in Llano County, Tex. Cryptocrystalline magnesite occurs principally in California. Magnesite occurrences have also been reported in several other States, including New Mexico, New York, New Jersey, Pennsylvania, Massachusetts, Vermont, and Maryland, but these deposits have not been developed commercially.

Some magnesite is difficult to distinguish from limestone and dolomite visually, but they can be identified by simple chemical tests. Neither magnesite nor dolomite containing no calcium carbonate in solid solution will effervesce in cold hydrochloric acid, whereas both limestone and magnesian limestone will effervesce. The following test will distinguish between magnesite and dolomite. Boil a fragment with dilute sulfuric acid (1 part of sulfuric acid to 6 parts water by volume, made by adding acid to water while stirring). The fragment, if it is magnesite or dolomite, will dissolve slowly. Magnesite gives a clear solution of magnesium sulfate, whereas the calcium in dolomite reacts with the sulfuric acid, leaving a white precipitate of calcium sulfate. If the magnesite sample contains a small percentage of lime, the lime will be precipitated as calcium sulfate, as with dolomite, but the bulk of the precipitate will be much less.

Brucite, magnesium hydroxide, $Mg(OH)_2$, theoretically analyzes 69.1 percent MgO and 30.9 percent H_2O. Crude brucite, because of its higher magnesia content, may be shipped profitably for longer distances than crude magnesite. The only known commercial deposit of brucite in the United States is in the Gabbs Valley or Luning, Nev., area. It is mined there by Basic Refractories, Inc., and shipped to Ohio for calcining. Brucite found in this area "has the appearance of freshly broken laundry soap. The color ranges from white through various shades of yellow to a brown. * * * The massive brucite will turn white on exposure to weather within a few months, but the coarsely crystalline material is not similarly affected. Weathered surfaces of brucite are covered by a hard, white, bony coating, which is generally crackled and reflects the underlying crystal structure."[4] Freshly broken brucite is generally soft and waxy, not unlike some varieties of talc. It is slowly soluble in warm hydrochloric acid, without effervescence.

Dolomite, magnesium-calcium carbonate, is theoretically the double salt $CaCO_3.MgCO_3$, but in practice the term dolomite applies also to high magnesian limestone. The theoretical magnesia content of dolomite is 21.9 percent, lime (CaO) 30.4, and carbon dioxide 47.7. Domestic dolomite deposits are widespread, but those being used as sources of magnesium oxide are located in Monterey County, near Salinas, Calif.; near Philadelphia, Pa.; in several areas in Ohio; and in West Virginia. The marketing of raw dolomite will not be discussed in this paper, as the subject is covered in other Bureau of Mines reports.[5]

---

[4] Callaghan, E., Brucite Deposit, Paradise Range, Nevada: Univ. of Nevada Bull., vol. 27, No. 1, January 16, 1933, p. 24.

[5] Bowles, Oliver, and Jensen, Mabel S., Limestone and Dolomite in the Chemical and Processing Industries: Bureau of Mines Inf. Circ. 7169, 1941, 15 pp.; Colby, Shirley F., Occurrences and Uses of Dolomite in the United States: Bureau of Mines Inf. Circ. 7192, 1941, 21 pp.

Dolomite is used both as primary and secondary sources of magnesia. As a primary source it supplies refractory magnesia by the process of the Standard Lime & Stone Co. and by the Pattinson process. The latter method involves dissolving the magnesia content of calcined dolomite as magnesium bicarbonate in reaction vessels containing carbon dioxide gas under pressure. When the remaining solution of magnesium bicarbonate is heated, a basic magnesium carbonate precipitates. In secondary processes, calcined dolomite is used with sea water and well brines to causticize the liquors and also to provide additional magnesia.

Raw sea water has an average content of 0.13 percent Mg, a theoretical equivalent of 1 pound of magnesium oxide per 55 gallons of sea water. On the California coast several salt works sell *sea-water bitterns* (from which the salt, NaCl, has been extracted) to the Westvaco Chlorine Products Corporation, Newark, Calif., as a raw material for the recovery of magnesium oxide. Sea-water bitterns contain 6.0 to 8.7 percent magnesium chloride and 4.2 to 6.1 percent magnesium sulfate.[6] Magnesium oxide is also being extracted from raw sea water by the Northwest Magnesite Co. at Cape May, N. J., for refractory use. In this process the sea water is causticized with calcined dolomite, and the magnesia content of the dolomite is added to that of the sea water. The pioneer producer of magnesia from sea water, however, is Marine Magnesium Products Corporation, with a plant at South San Francisco, Calif., where high-grade pharmaceutical and specialty magnesias have been produced since about 1928.[7]

Magnesium-bearing liquors are rarely sold on the open market, and their marketing is therefore not discussed herein.

Michigan *well brines,* said to contain about 1.25 pounds of Mg per gallon, were used as sources of magnesia for the first time in 1942. The wells are sunk several thousand feet into brine-bearing strata, and the brine is brought to the surface with centrifugal pumps. The Michigan Chemical Corporation plant at St. Louis, Mich., uses calcined dolomite to causticize and enrich well brines for the manufacture of refractory and caustic-calcined magnesia.

Magnesium silicates, including olivine and serpentine, of which there are huge deposits, have not yet been used commercially to produce magnesium oxide, but they are used as sources of other magnesium compounds and may be regarded as potential sources of magnesia.

MINING

Magnesite is mined by both open-pit and underground methods. In Stevens County, Wash., magnesite occurs as huge, steeply pitching lenses in dolomite beds overlain by quartzite. The magnesite is quarried from three large open pits and sent by aerial tramways down the hillside to crushing and calcining units on a rail spur. Quarrying methods also are used to recover magnesite and brucite in Nevada. In California, magnesite generally occurs in veins and is won by underground mining. Dolomite is usually recovered by quarrying. The overburden is

---

[6] Seaton, Max Y., Production and Properties of the Commercial Magnesias: Am. Inst. Min. and Met. Eng., Tech. Pub. 1496, July 1942, 21 pp.

[7] Chesny, H. H., Magnesium Compounds from Ocean Waters: Ind. Eng. Chem., vol. 28, No. 4, April 1936, pp. 383-390.

removed, the dolomite is broken out by blasting, loaded by power shovels into trucks or quarry cars, and hauled to the surface for washing and crushing.

PREPARATION BEFORE CALCINING

Impurities consisting of magnesium silicate and dolomite veins that interleaf massive Washington magnesite are removed by handpicking after the rock is blasted from the quarry wall. The impurities, it is said, can be distinguished visually with fair certainty. Flotation plants recently introduced at Chewelah, Wash., and near Luning, Nev., are employed to treat magnesite and yield a high-quality magnesite low in fluxes such as silica, iron oxide, and lime. At the Washington flotation plant, raw magnesite is reduced successively in a jaw crusher to 8-inch size, in a gyratory crusher to about 3-inch size, and in a cone crusher to minus ¼-inch. It is then further reduced in a ball mill to about 65-mesh. Classifiers pass the fines to flotation cells, and the coarse particles are returned to the ball mill. In the 32 flotation cells, magnesium carbonate is separated from impurities, and the relatively pure product passes into a thickener, where excess water is removed, after which the product is calcined. The beneficiated Washington magnesite is used in making magnesia refractory brick, whereas the beneficiated Nevada magnesite is used to make magnesium metal. The magnesite mined by the Sierra Magnesite Co. near Luning, Nev., is pure enough for use without beneficiation, although the silica content may be reduced by screening out the fines, which are higher in silica than the coarser product. This method is also employed with some of the California magnesites.

The problems encountered in beneficiating magnesite are discussed in several reports.[8]

CALCINING RAW MAGNESITE

Virtually all magnesite (and brucite) is calcined before use, either to render the magnesia content highly reactive (caustic-calcined magnesite) or to render it as unreactive as possible (dead-burned magnesite). The uses of the two calcination products are quite dissimilar. The former is used in plastic magnesia flooring, fertilizers, and various chemicals and for making magnesium metal, whereas nearly all dead-burned magnesia is used in refractories. As calcination is an essential process, the industry has been developed chiefly by a few firms possessing sufficient capital to furnish the necessary kilns and accessories. The smaller magnesite miners sell their raw magnesite to the larger miners, who have calcining equipment.

Rotary kilns and Herreshoff vertical furnaces have superseded older types of kilns. The seven oil-fired kilns installed at Chewelah, Wash., are 125 feet long and either 7 feet 6 inches or 8 feet in diameter, with hot-zone linings of magnesite brick. Each kiln has a capacity of 100 to 150 tons of dead-burned magnesite per day. About 2.2 tons of raw material is required per ton of finished product. The incandescent dead-

[8] Clemmer, J. B., Doerner, H. A., and DeVaney, F. D., Experimental Flotation of Washington Magnesite Ores: Am. Inst. Min. and Met. Eng., Tech. Pub. 1148, 1940, 10 pp.
Sinkinson, Eric, and Michaelson, S. D., Flotation of California Magnesites: Am. Inst. Min. and Met. Eng., Tech. Pub. 733, 1935, 8 pp.
Doerner, H. A., and Harris, Dwight L., Concentration of Low-Grade Magnesite Ores by Flotation: State College of Washington Bull. P-1, 1938, 30 pp.

burned magnesite emerging from the kilns is passed through rotary coolers and then crushed by rolls and sorted by screens into sizes required by the trade. Dust is recovered from kiln gases by means of a Cottrell precipitator. Part of it is returned to the kiln, part is utilized in by-products, and the part lowest in purity is wasted. Pure magnesite fuses at about 2,800° C., but owing to the fluxes present in Chewelah maintenance-grade magnesite, a calcining temperature of only about 1,560° C. is necessary for crystal growth.

At the Bald Eagle mine of the Westvaco Chlorine Products Corporation, near Gustine, Calif., magnesite is calcined in an oil-fired rotary kiln 100 feet long, 6 feet outside diameter, and 4½ feet inside diameter. The hot zone (40 feet long) is lined with periclase brick. A temperature of 1,760° C. is maintained for periclase production and 800 to 1,200° C. for caustic-calcined magnesite.

Basic Magnesium, Inc., calcines its flotation magnesite to caustic grade in four Herreshoff roasters 60 feet in height and 22 feet in diameter on the theory that this type of kiln is better adapted to calcining fines than the rotary kiln. The Herreshoff roaster consists of a series of circular hearths, one on top of the other. The fines are fed into the top hearth and plowed by revolving arms, so that the material moves toward the central shaft and drops on the hearth beneath. This action occurs successively until the calcined fines are discharged near the bottom of the furnace. Each furnace has a capacity of about 100 tons of caustic-calcined magnesia per day.

A distinction is frequently made in the terms "periclase" and "dead-burned magnesite," though the latter, by definition, includes the former. Periclase is recognized in the trade as magnesia analyzing over 90 percent MgO, calcined at about 1,760° C., whereas dead-burned magnesite analyzes from 65 to 88 percent MgO and is calcined at about 1,560° C. There is some overlapping in analyses of the two grades, as some periclase might analyze as low as 85 percent MgO, in which case it would qualify as a periclase solely because of the higher temperature at which it had been calcined.

SPECIFICATIONS

Crude magnesite. The main requisite of a marketable crude magnesite is a high magnesia content. Although magnesite theoretically contains 47.8 percent MgO, such purity is never encountered in nature. Any given sample of magnesite is appraised on a calcined basis, either caustic-calcined or dead-burned, as very little crude magnesite is consumed as such without previous calcining. The lowest grade of commercial crude magnesite contains about 43 percent MgO. Permissible impurities are variable, depending on the prospective use of the crude material.

The impurities permissible in raw magnesite which is to be dead-burned are variable, depending on whether the ultimate use is as grain magnesite or as a constituent of magnesite brick. Certain impurities necessary for the manufacture of grain magnesite are permissible in only small quantities in magnesite used in brickmaking. From 4 to 7 percent Fe_2O_3 is desirable in dead-burned grain magnesite for certain brick and maintenance grades. Roll scale or iron ore may be added if not enough iron is initially present. Iron forms such bonding agents

as calcium ferrite, $2CaO.Fe_2O_3$, and magnesium ferrite, $2MgO.Fe_2O_3$, the former under conditions of high lime and low silica, the latter when lime is low and silica high. Iron is present in Austrian magnesite in the form of iron carbonate, which decomposes and causes the magnesite to sinter at lower temperatures than if the iron were present as oxide. Silica should be present only in silicate form, which provides a binder for the grains when applied to the furnace bottom. The alumina (Al_2O_3) content generally should not exceed 2.5 percent (dead-burned basis), but alumina is interchangable to some extent with Fe_2O_3, and in maintenance-grade magnesia a higher content may be allowed, possibly as high as 5 percent, without detriment. For periclase manufacture the maximum Al_2O_3 permissible is 0.3 percent calcined basis. The following analysis is typical of Washington magnesite in the crude state, previous to addition of iron oxide: MgO 42.5, SiO_2 4.2, Fe_2O_3 0.96, Al_2O_3 0.41, CaO 2.76, H_2O 0.06, and CO_2 48.6 percent.

The following analysis is typical of crude magnesite for oxychloride use (crude basis) : MgO 43.3, CO_2 48.7, SiO_2 5.7, Fe_2O_3 1.3, Al_2O_3 0.3, and CaO 0.9 percent. On calcining, the CO_2 content is reduced to about 2.2 percent, increasing the other percentages, thus: MgO 82.5, SiO_2 11.0, Fe_2O_3 2.0, Al_2O_3 0.5, and CaO 1.8 percent. Lime in the form of quicklime or hydrated lime is the impurity most detrimental in magnesite for this use, but calcium silicate and calcium carbonate are harmless. Active lime should not exceed 3.5 to 4 percent, crude basis, as it causes excessive expansion in oxychloride cements. Silica, if present, should be in the form of silicates or as comparatively large grains of SiO_2. Fine silica tends to flux the MgO to form magnesium silicates when the magnesite is calcined.

Maximum impurities desired by Basic Magnesium, Inc., in magnesite for metal use are CaO 1.5, SiO_2 1.0, R_2O_3 (principally $Fe_2O_3+Al_2O_3$) 1.0 percent, caustic-calcined basis. However, from time to time circumstances have forced the use of less pure material, particularly with respect to lime.

Dead-burned magnesia. Theoretically, dead-burned magnesia has no ignition loss, but actually it may be about 0.5 percent. Low porosity is an important requisite of brickmaking grades of dead-burned magnesia. The following analysis is typical of dead-burned Washington maintenance-grade magnesia: MgO 80.89, SiO_2 6.95, Fe_2O_3 5.03, Al_2O_3 1.25, and CaO 5.59 percent. A typical analysis of dead-burned Washington brickmaking-grade magnesia is: MgO 83.0, SiO_2 6.6, Fe_2O_3 4.4, Al_2O_3 1.7, and CaO 3.2 percent. Some of the iron content in both analyses is derived from iron ore, which is added to the raw magnesite in a ratio of 2.25 to 100 before calcining, so that the material will sinter at a lower temperature. Number 90 periclase from the Western mine of the Westvaco Chlorine Products Corporation near Livermore, Calif., has the following approximate analysis: MgO 90.9, SiO_2 5.8, Fe_2O_3 1.1, Al_2O_3 0.2, and CaO 2.0 percent. The largest consumer of periclase (for the manufacture of refractories) has furnished the following specification for periclase: Fe_2O_3 0.50 percent maximum, SiO_2 5.50 maximum, CaO 2.00 maximum, Al_2O_3 0.30 maximum, MgO 90.00 minimum, and ignition loss 0.25 maximum.

Caustic-calcined magnesia. Caustic-calcined magnesia should generally contain 1 to 5 percent CO_2+H_2O, though special-purpose grades may contain as much as 8 percent. It should not be stocked long, as it tends to rehydrate and recarbonate. Time and temperature of calcination should be controlled carefully, because underburned caustic magnesia sets too rapidly in oxychloride cements whereas overburned caustic magnesia sets too slowly and makes a weak cement. Caustic-calcined magnesite is shipped in lump form to distributors where it is ground so that 90 percent passes a 200-mesh screen. The powdered material is then sold to the ultimate consumers.

USES

Crude magnesite. Relatively small quantities of crude magnesite are consumed without calcining. It is used mainly in making Epsom salt by reaction with sulfuric acid.

Dead-burned magnesia. As previously mentioned, dead-burned magnesia has only one use—refractories. (A small amount of incompletely calcined dust from dead-burning furnaces is used as fertilizer, but this is generally regarded as caustic-calcined by the trade.) About 88 percent (average for 5-year period 1938-42) of the magnesia produced in the United States is dead-burned. Much of this is crushed and classified for use as grain magnesia, which is used to provide a working hearth in basic open-hearth steel furnaces and for maintenance and repair of the furnaces during the ensuing campaigns. The remainder is used in making brick and cement for basic refractory purposes, mostly in the steel industry.

Magnesia is used in making 8 standard types of bricks, as follows:

A. Fired brick
  1. Made from magnesia, without incorporation of chrome ore
    (a) Low iron oxide content
    (b) High iron oxide content
  2. Magnesia with chrome ore
    (a) Low iron oxide content
    (b) High iron oxide content

B. Unfired brick (same subclassifications as under A)

Most basic brick contain a considerable percentage of chrome ore; generally the brick formula calls for more chrome ore than magnesia. It is estimated that in over-all open-hearth practice, about 15 chrome or chrome-magnesia brick are used to every magnesia brick containing no chrome. About as many brick are used fired as unfired. It is said that the unfired brick are suitable for most purposes after drying.

In constructing the conventional type of basic open hearth, a few inches (about 1½ to 5) of insulation in the form of a fill, concrete, or brick, is placed on the steel shell forming the bottom of the furnace, followed by two or three courses of fire-clay brick and then 7½ to 18 inches of chrome or chrome-magnesia brick. In older practice the subhearth, which was made with magnesia brick, was given a slag wash or a thin covering of magnesia cement to seal the interstices of the brick. In the last 10 years, however, many new and rebuilt open hearths have incorporated a 6-inch layer of plastic chrome ore directly on the subhearth, burnt in at 2,900° F. or higher; this layer gives increased protection against a breakout of metal, should the magnesia working hearth develop seepages. Grain

magnesia, mixed with 5 to 25 percent of its weight of slag, is spread in a one-inch layer directly on the subhearth (that is, either on the brick subhearth or the plastic chrome ore subhearth), and the furnace is fired for 24 hours and other layers are added successively until a 6- to 10-inch monolithic working hearth has been built up. If the furnace is properly insulated, the 20 to 70 tons of grain magnesia used as the working hearth can be sintered in 3 to 15 days, during which time 210 to 630 tons of coal or its equivalent may be consumed. After the hearth has been completed, the furnace is ''washed out'' with molten slag to seal crevices in the bottom. During the ensuing campaigns, grain magnesia, grain dolomite, and proprietary magnesia and chrome ore maintenance materials may be used to patch portions of the hearth that may have floated out or have been damaged by the charge. Dead-burned grain dolomite is by far the principal material used for furnace patching, though considerable raw dolomite is also used. Dead-burned dolomite is preferred to magnesite as a patching material for economic reasons and because of the ease with which dolomite fuses into the furnace bottom and becomes a part of the working hearth.

During the war emergency, rammed bottoms of proprietary magnesia or chrome ore composition have been used instead of the magnesia-slag working hearths described above to get the furnaces into production in the shortest possible time. Basic Refractories, Inc., Cleveland, Ohio, prepares such a magnesia grain by calcining brucite (mined near Luning, Nev.) with dolomite and certain other materials. The resulting refractory analyzes about MgO 65, SiO_2 7.0, Fe_2O_3 7.5, Al_2O_3 1.0, and CaO 18.0 percent.[9] Basic-steel furnace bottoms of this type of refractory, it is claimed, can be rammed to a depth of 15 inches directly on brick much more rapidly than the usual magnesia working hearth can be burned in, evidently an important consideration in wartime. No evidence is yet available as to the life of a brucite-dolomite bottom.

The Standard Lime & Stone Co., Millville, W. Va., produces a grain refractory analyzing MgO 70.0, SiO_2 7.5, $Al_2O_3+Fe_2O_3$ 8.0, and CaO 14.5 percent for use in basic open-hearth maintenance and repair. The material is derived from calcined dolomite by leaching out the more soluble lime with CO_2-free water.

Electric basic-steel furnaces operate at higher temperatures than open-hearth furnaces and require more stable refractories than those used in the open-hearth furnace. Grain magnesia for electric furnaces is necessarily purer (analyzing over 90 percent MgO) than ordinary maintenance grain, so that formation of low-melting glasses between the crystals of periclase in the bottom will be small, that is, just enough to bond the bottom. The present trend is toward the use of fired magnesia brick in the electric furnace, replacing grain bottoms.

A well-maintained basic open hearth may last 8 to 20 years without a rebuild. Electric furnaces do not generally last nearly so long, but through no fault of the refractories; the bottom is ordinarily torn out and replaced whenever the grade of steel or alloy being made is changed, to avoid contamination.

Magnesia brick are not used in the roofs of American basic open hearths, as the brick are structurally weak at the temperature of the open

[9] For a discussion of dolomite-magnesia refractories see Schallis, A. H., Dolomite-Base Refractories: Bureau of Mines Inf. Circ. 7227, 1942, 11 pp.

hearth—about 1,585° C. Silica brick are used instead; but even with silica brick the roof softens at about 1,650° C. Considerable research is in progress to develop a brick that retains structural strength and spalling resistance at temperatures above 1,650° C., and promising experimental results have been obtained with specially prepared brick made from magnesia and chrome ore.

Following is a description of a typical process for making refractory brick from dead-burned magnesia. If the plant receives dead-burned magnesia in lump form, the lumps are reduced in primary and secondary crushers to a predetermined mesh ratio, and the grain thus formed is ground and separated into several screen sizes. The smaller particles help fill voids when the brick is pressed. Various screen sizes of the material, in proper proportion, are weighed out into edge-runner mixing pans, and a little binder, inorganic (such as kaolin) or organic (such as sulfite pitch or dextrin), is added to help hold the brick together before it is dried. The mix is now ready to be pressed. Virtually all magnesia brick are formed in a dry press capable of exerting pressure up to 14,000 pounds per square inch. A four-sided bottomless box resting on a steel platform in back of the machine, fed by a reservoir of mix, moves forward automatically and drops a load of mix into one or more brick-size depressions beneath the poised plungers. The plungers descend and press the prepared mix into brick, the plungers rise, and the brick are automatically ejected. The brick are placed on steel pallets, and the load is trundled to a long oven nearby, where the brick are dried. When dry, the bricks are taken to periodic kilns, stacked on silica-brick supports and fired at 2,880° F. (1,582° C.) for eight days. The kiln is then allowed to cool, and the brick are removed and either loaded directly on cars for shipment or stored. One plant uses a tunnel kiln for firing;[10] a temperature of 3,200° F. (1,760° C.) is maintained in the hot zone, and a kiln car passes through the kiln in about 3 days.

Much dead-burned magnesia and periclase is mixed with chrome ore in the manufacture of refractory brick. A smaller quantity is mixed with olivine in making refractories.

Besides being used in basic open-hearth furnaces and basic electric-arc and induction furnaces, magnesia brick and grain are used in the production of several nonferrous metals, particularly copper. The roof of the copper reverberatory furnace, according to Norton,[11] is exposed to a great deal of dust, which fuses and produces a severe slag attack. Silica brick are still used in these roofs in spite of fluxing effect. Within the last few years, chemically-bonded chrome-magnesia brick have been used quite extensively for constructing suspended roofs for the entire furnace arch. These roofs are used almost universally in Canada and are found to last many times longer than the former silica roofs.[12] The brick are also used in side walls at the slag line. Copper converters and holding furnaces are generally lined with magnesia or chrome-magnesia brick. A layer of grain magnesite is placed between the brick lining and the converter shell. In the anode reverberatory furnace, where the copper is further refined, magnesite brick are used in the side walls to a

[10] Housman, G. S., and Seil, G. E., Modern Practice Crystallized in New Tunnel Kiln: Chem. and Met. Eng., vol. 36, No. 6, June 1929, pp. 340-343. (Practice has been modified in several respects since the article was written.)

[11] Norton, F. H., Refractories: McGraw-Hill Book Co. Inc., New York, 2d ed., 1942, p. 648.

[12] Chemistry and Industry (London), vol. 61, No. 5, January 31, 1942, p. 62.

point slightly above the slag line (the bottom generally being ganister rammed on fire-clay brick). Silica brick are generally used above the slag line but chemically bonded and metal-cased magnesia brick also have been used successfully. Magnesia brick have also replaced to some extent the more common silica brick in sections of the anode furnace roof, extending the roof line. In the induction furnace used to melt high-melting-point copper alloys, electrically fused or high-grade kiln-burned periclase mixed with a little sodium silicate has been rammed into the furnace shell.

Magnesia brick are used in lead-refining furnaces at the slag line, where corrosion would otherwise be severe. Magnesia brick are used similarly in lead-drossing furnaces.

Magnesia blocks are used frequently in the hot zones of rotary kilns for cement, lime, dolomite, and magnesite. Steel sheets are inserted between the individual blocks. Though initially more expensive than alumina brick, magnesia brick may prove more economical over a long period.[13]

Magnesia brick are now being used as checker brick in glass furnaces, and brick containing magnesia and chrome ore are used in the ports and uptakes of these furnaces.

Comber [14] has summarized refractory uses of magnesite.

Caustic-calcined magnesia. Magnesium oxychloride (Sorel) cements are commonly prepared by mixing a solution of 22° B. (about 20 percent) magnesium chloride with finely ground caustic-calcined magnesia and inert fillers, such as cork and sawdust. The mixture sets in 3 to 4 hours and under the microscope appears as an amorphous mass containing few crystals, homogenous except for grains of uncombined magnesia. It is thought that this solid solution of MgO in $MgCl_2.XH_2O$ may contain such definite oxychloride compounds as $3MgO.MgCl_2.7H_2O$, $5MgO.MgCl_2.14H_2O$, and $10MgO.MgCl_2.14H_2O$.

The principal use of oxychloride cement during the 1920's, when the industry was at its height, was for outside stucco. This use gradually declined owing to the low weather resistance of the stuccos as then applied, caused in part by improper formulation and poor workmanship. Addition of copper powder to outside oxychloride cements is said to increase weather resistance tremendously.[15]

One square yard of stucco in place is said to weigh about 32 pounds,[16] of which 4.6 is caustic-calcined magnesia; the remainder is magnesium chloride, water in combination, and aggregates.

Oxychloride flooring, the chief use of plastic magnesia at present, contains about 1 pound of magnesia per square foot. Such flooring is of particular value in factories, ship decking, hospitals, and railroad cars, as it is permanent, resilient, fireproof, and can be laid over old or new wooden floors. Also it may be sawed or cut, and attachments may be made to it with nails or screws. In commercial practice the ground plastic magnesia and the magnesium chloride are usually mixed at the point of application.

---

[13] Rochow, W. F., Magnesite Linings in Kilns: Rock Products, vol. 41, No. 4, April, 1938, pp. 82-83.

[14] Comber, A. W., Magnesite as a Refractory: J. B. Lippincott Co., 1937, 114 pp.

[15] Hubbell, D. S., A New Organic Cement and Adhesive: Ind. Eng. Chem., vol. 29, No. 2, February 1937, pp. 123-132.

[16] Ralston, O. C., Pike, R. D., and Duschak, Lionel H., Plastic Magnesia: Bureau of Mines Bull. 236, 1925, p. 7.

Miscellaneous uses of oxychloride cement include abrasive wheels, artificial stone, small molded articles such as pipe bowls and casket handles, and fireproof heat-insulating wallboard. For some uses, particularly in wallboard, magnesium sulfate solution may be substituted for magnesium chloride solution.

Two basic processes make use of caustic-calcined magnesia as a raw material in the manufacture of magnesium metal. In one, the magnesia is reduced with finely divided carbon (carbothermic or Hansgirg process, as practiced by Permanente Metals Corporation, using magnesia obtained from raw sea water); in the other the magnesia is reacted with dry chlorine gas in the presence of carbon, producing an anhydrous magnesium chloride. The magnesium chloride is fused and electrolyzed. The second process is used by Basic Magnesium, Inc., at Las Vegas, Nev. Research by the Bureau of Mines indicates that calcined magnesia may be fed directly to the electrolytic cell—a third possible basic process. Fellom has recently reviewed the carbothermic and electrolytic processes.[17]

Caustic-calcined magnesia from sea-water bitterns is used extensively as a catalyst in the manufacture of synthetic rubber.

The use of magnesia as a fertilizer is growing. It has been found that many soils are deficient in magnesium and that an active grade of magnesia will supply this element satisfactorily. The magnesia used for this purpose is often mixed with commercial fertilizers, not only to furnish magnesium but also to absorb moisture (or excess acid from superphosphate) and otherwise to condition the fertilizer to prevent lumping and produce a free-flowing, easily usable material.

A typical analysis of fertilizer-grade caustic-calcined magnesite is MgO 82.8, SiO_2 9.0, Fe_2O_3 0.8, Al_2O_3 1.2, CaO 3.2, and ignition loss 2.0 percent.

Specially prepared caustic-calcined magnesia is used to clarify and adsorb impurities from petroleum lubricants, dry-cleaning solvents, and other nonaqueous and unreactive fluids. The magnesia is precipitated from magnesium-bearing brines either as $MgCO_3$ or $Mg(OH)_2$ and calcined at a dull red heat (from 325° to 430° C.). The resulting material is agitated with the oil, and then the oil is filtered off, leaving many of the discoloring impurities and much of the carbonaceous matter adsorbed on the magnesia.

Caustic-calcined magnesia has been considered as an agent for recovering sulfur dioxide from flue gases for subsequent use in the manufacture of sulfuric acid. The reactions would be $MgO + SO_2 \rightarrow MgSO_3$; $MgSO_3 + \text{heat} \rightarrow MgO + SO_2$.[18]

Other uses of caustic-calcined magnesia are in the manufacture of Epsom salt, basic magnesium carbonate ("technical carbonate") for thermal insulation, and glass and in the removal of silica from boiler water.

PRICES

The prices of magnesia products, with the exception of California dead-burned grain, have remained relatively constant since 1936, as may be seen from table 1. It will be noted that the price of refractory magne-

[17] Fellom, Roy, Jr., Magnesium: Light Metal Age, vol. 1, No. 1, May 1943, pp. 9, 16.
[18] Chemical and Metallurgical Engineering, vol. 49, No. 3, March 1942, p. 151.

sia increases rapidly as the purity of the product improves. This is largely because of the difficulty in sintering the purer grades of magnesia; and exceedingly high temperatures are required to produce artificial periclase, especially from precipitated magnesia.

TABLE 1. Trade-journal quotations of domestic magnesia products per short ton, 1936-43 [1]

	1936	1937	1938	1939
Dead-burned grain magnesite:				
Washington	$22 00	$25 00	$25 00	$22 00
California	25 00	25 00	25 00	25 00
Artificial periclase:				
94-per cent grade	65 00	65 00	65 00	65 00
90-per cent grade	35 00	35 00	35 00	35 00
Caustic-calcined magnesite:				
95-per cent grade, white	40 00	40 00	40 00	40 00
85-per cent grade	37 50	37 50	37 50	37 50

	1940	1941	1942	1943 (August)
Dead-burned grain magnesite:				
Washington	$22 00	$22 00	$22 00	$22 00
California	25 00	25 00	40 50	40 50
Artificial periclase:				
94 per cent grade	65 00	65 00	65 00	65 00
90 per cent grade	35 00	35 00	35 00	35 00
Caustic-calcined magnesite:				
95 per cent grade, white	40 00	40 00	40 00	40 00
85 per cent grade	37 50	37 50	37 50	37 50

[1] Engineering and Mining Journal (Metal and Mineral Markets) quotations, f.o.b. shipping points in Washington or California.

MAGNESIA SALES, BY SOURCES, IN 1942

TABLE 2. Magnesia sold or used by producers in the United States in 1942, by kinds and sources

(Quantities and values reported apply to finished products, not raw materials)

Finished products	From magnesite		From brucite, dolomite and sea-water bitterns		From well brines, dry-lake brines, and raw sea water	
	Short tons	Value	Short tons	Value	Short tons	Value
Caustic-calcined	19,551	$798,019	(1)	(1)	(1)	(1)
Refractory	189,218	4,397,766	(1)	(1)	(1)	(1)
Totals	208,769	$5,195,785	[2]93,521	[2]$3,907,396	[3]7,467	[3]$497,434

[1] Included in "Total."
[2] Includes caustic-calcined and refractory magnesia and magnesia from precipitated carbonate.
[3] Includes caustic-calcined and refractory magnesia and magnesia from precipitated carbonate and from magnesium hydroxide.

SALIENT STATISTICS OF THE MAGNESIA INDUSTRY

TABLE 3. Salient statistics of the magnesia industry in the United States, 1933-42

Year	Caustic-calcined magnesia				Year	Dead-burned magnesia			
	[1]Sold by producers		Imports for consumption			[2]Sold by producers		Imports for consumption	
	Short tons	Value	Short tons	Value		Short tons	Value	Short tons	Value
1933	4,835	$143,250	1,850	$33,081	1933	46,919	$880,740	23,509	$341,780
1934	4,110	120,525	1,553	36,031	1934	41,953	772,233	22,921	368,014
1935	6,049	170,326	1,441	36,076	1935	72,438	1,361,949	24,674	429,830
1936	7,998	221,410	2,196	49,674	1936	89,979	1,713,527	42,608	662,567
1937	10,031	311,326	2,798	62,420	1937	83,204	1,598,336	56,021	795,047
1938	7,400	228,498	1,452	39,551	1938	38,738	730,978	24,990	371,669
1939	10,157	310,102	2,218	51,884	1939	86,077	1,699,723	44,420	800,664
1940	16,261	512,607	928	21,301	1940	140,668	2,802,537	30,951	551,536
1941	30,225	1,052,077	[3]527	[3]11,538	1941	201,481	5,052,879	[3]36,574	[3]802,844
1942	35,485	1,540,573	([4])	([4])	1942	273,661	7,823,963	([4])	([4])

[1] 1933-41: Includes caustic-calcined magnesite and caustic-calcined magnesia from sea-water bitterns; 1942: Includes caustic-calcined magnesite and caustic-calcined magnesia from sea-water bitterns, well brines, and raw sea water.

[2] 1933-40: Includes dead-burned magnesite and refractory magnesia from sea-water bitterns; 1941: Includes dead-burned magnesite and refractory magnesia from brucite, dolomite, and sea-water bitterns; 1942: Includes dead-burned magnesite and refractory magnesia from brucite, dolomite, sea-water bitterns, well brines, and raw sea water.

[3] Figures cover January to September, inclusive.

[4] Figures not available for publication.

BUYERS

Possible buyers of crude magnesite and brucite

Basic Refractories, Inc., 845 Hanna Bldg., Cleveland 15, Ohio.
Meramec Minerals, Inc., 723 Hanna Bldg., Cleveland 15, Ohio.
Northwest Magnesite Co., 1800 Farmers Bank Bldg., Pittsburgh 22, Pa.
Permanente Metals Corporation, Permanente, Calif.
Westvaco Chlorine Products Corporation, 405 Lexington Ave., New York 17, N. Y.

Possible buyers of dead-burned magnesia

Following is an incomplete list of firms operating basic open-hearth steel furnaces that use dead-burned magnesia. Not all of the branch plants of the larger firms are listed, and many firms that operate only a few hearths are not listed at all.

Tennessee Coal, Iron & Railroad Co., Birmingham, Ala. (Hearths at Fairfield, Ala.)
Columbia Steel Co., San Francisco, Calif. (Hearths at Pittsburg, Calif.)
Kaiser Co., Inc., Fontana, Calif.
Colorado Fuel & Iron Corporation, Pueblo, Colo.
Republic Steel Corporation, Cleveland, Ohio. (Hearths at Chicago, Ill.; Cleveland, Ohio; Youngstown, Ohio; and Canton, Ohio.)
Wisconsin Steel Co., South Chicago, Ill.
Granite City Steel Co., Granite City, Ill.

Inland Steel Co., Indiana Harbor, Ind.
American Rolling Mill Co., Middleton, Ohio. (Hearths at Ashland, Ky., and St. Louis, Mo.)
Andrews Steel Co., Newport, Ky.
Bethlehem Steel Co., Bethlehem, Pa. (Hearths at Sparrows Point, Md.; Lackawanna, N. Y.; Bethlehem, Pa.; Johnstown, Pa.; Steelton, Pa.; and Seattle, Wash.)
Wheeling Steel Corporation, Wheeling, W. Va. (Hearths at Steubenville, Ohio, and Portsmouth, Ohio.)
National Tube Corporation, Pittsburgh, Pa. (Hearths at Lorain, Ohio.)
Youngstown Sheet & Tube Co., Youngstown, Ohio. (Hearths at Campbell, Ohio.)
Allegheny Ludlum Steel Co., Pittsburgh, Pa. (Hearths at Brackenridge, Pa.)
Carnegie-Illinois Steel Corporation, Pittsburgh, Pa. (Hearths at Clairton, Pa.; Munhall, Pa.; Braddock, Pa.; and Duquesne, Pa.)
Jones & Laughlin Steel Corporation, Pittsburgh, Pa.
Lukens Steel Co., Coatesville, Pa.
Alan Wood Steel Co., Conshohocken, Pa. (Hearths at Ivy Rock, Pa.)
Pittsburgh Steel Co., Pittsburgh, Pa. (Hearths at Monessen, Pa.)
National Steel Co., Pittsburgh, Pa. (Hearths at Weirton, W. Va.)

The following producers of basic refractories are also possible purchasers of dead-burned magnesia:

Basic Refractories, Inc., 845 Hanna Bldg., Cleveland 15, Ohio.
General Refractories Co., 1600 Real Estate Trust Bldg., Philadelphia 7, Pa.
Harbison-Walker Refractories Co., 1800 Farmers Bank Bldg., Pittsburgh, Pa.
E. J. Lavino and Co., 1528 Walnut St., Philadelphia, Pa.

Possible buyers of caustic-calcined magnesia

American Enka Corporation, Enka, N. C.
Armour Fertilizer Works, 816 Walton Bldg., Atlanta, Ga.
Asbestolith Mfg. Corporation, 257 Kent St., Brooklyn, N. Y.
Consolidated Tile & Deck Coverings, 101 Park Ave., New York 17, N. Y.
Dow Chemical Co., Midland, Mich.
Electro-Metallurgical Co., 30 E. 42d St., New York 17, N. Y.
General Electric Co., 1 River Road, Schenectady, N. Y.
Goodyear Tire & Rubber Co., 1144 E. Market St., Akron 16, Ohio.
Hill Brothers Chemical Co., 2159 Bay St., Los Angeles 21, Calif.
Lasting Products Co., 202 S. Franklintown Road, Baltimore, Md.
The Mathieson Alkali Works, Inc., P. O. Box 583, Lake Charles, La.
National Tile & Marble Corporation, 529 W. 46th St., New York, N. Y.
North American Rayon Corporation, P. O. Box 551, Elizabethton, Tenn.
Norton Co., 1 New Bond St., Worcester 6, Mass.
Chas. Pfizer & Co., Inc., 11 Bartlett St., Brooklyn 6, N. Y.
F. E. Schundler & Co., Inc., 504 Railroad St., Joliet, Ill.
F. E. Schundler & Co., Inc., 45-15 Vernon Blvd., Long Island City, N. Y.
Westvaco Chlorine Products Corporation, 405 Lexington Ave., New York, N. Y.

WORLD PRODUCTION OF MAGNESITE

TABLE 4. World production of magnesite, 1933-39, by countries, in metric tons [1]

(Compiled by B. B. Waldbauer)

Country	1933	1934	1935	1936	1937	1938	1939
Anglo-Egyptian Sudan	----------	----------	256	----------	----------	(2)	----------
Argentina	----------	----------	----------	----------	----------	----------	50
Australia:							
New South Wales	9,512	15,902	15,940	17,459	19,807	19,465	25,207
Queensland	152	42	102	102	----------	----------	----------
South Australia	205	208	51	118	71	231	382
Victoria	6	26	335	219	143	122	119
Western Australia	----------	----------	----------	----------	----------	10	----------
Canada[3]	27,158	27,385	27,112	(4)	(4)	(4)	(4)
China (Manchuria)	71,376	100,329	225,654	191,568	331,000	[5]171,713	[5]247,784
Chosen	(2)	3,168	2,410	14,258	37,000	(2)	(2)
Czechoslovakia[6]	49,929	58,235	70,838	83,270	92,143	74,707	(2)
Germany:							
Austria	164,331	258,382	300,312	397,776	459,233	[7]415,000	[7]500,000
Prussia	(2)	11,010	13,818	15,026	21,091	23,860	(2)
Greece	44,719	70,388	93,563	116,106	161,676	168,243	126,786
India, British	15,450	15,215	17,257	15,716	26,586	26,022	34,107
Italy	2,187	1,100	1,251	3,153	5,392	6,157	(2)
Norway	2,007	2,500	2,526	3,116	2,096	2,098	2,767
Turkey	951	628	1,092	2,247	1,365	846	435
Union of South Africa	1,495	1,667	1,485	1,694	1,752	2,615	4,022
U. S. S. R.	380,300	482,000	475,000	[7]500,000	[7]550,000	[7]600,000	[7]650,000
United States	98,145	91,601	160,711	187,894	184,554	88,000	180,511
Yugoslavia (Serbia)	14,602	25,086	30,225	39,008	41,967	40,779	32,887

1 Unless otherwise stated, quantities in this table represent crude magnesite mined.
2 Data not available.
3 Magnesitic dolomite.
4 Data for production not available; value reported as follows: 1936, $768,742; 1937, $677,207; 1938, $420,261; 1939, $474,418.
5 Exports.
6 Exports, less imports, of crude and sintered magnesite, the sintered being reduced to crude on the basis of 2.1 tons crude to 1 ton sintered.
7 Estimated production.

PRODUCERS

Producers of magnesia in the United States

Company	Office address	Location of plant	Type of magnesia produced
From magnesite:			
Basic Magnesium, Inc.	Las Vegas, Nev.	Luning, Nev.	Caustic-calcined
Northwest Magnesite Co.	1800 Farmers Bank Bldg., Pittsburgh, 22, Pa.	Chewelah, Wash.	Caustic-calcined, dead-burned
Permanente Cement Co.	Permanente, Cal.	Permanente, Cal.	Caustic-calcined
Westvaco Chlorine Products Corporation	405 Lexington Ave., New York, 17, N. Y.	Gustine, Cal.	Caustic-calcined, dead-burned
do.	do.	Patterson, Cal.	Caustic-calcined, dead-burned
do.	do.	Livermore, Cal.	Dead-burned
do.	do.	Newark, Cal.	Caustic-calcined
From brucite:			
Basic Refractories, Inc.	845 Hanna Bldg., Cleveland, 15, Ohio	Luning, Nev.	Dead-burned
From dolomite:			
Standard Lime and Stone Co.	2000 First National Bank Bldg., Baltimore, 3, Md.	Millville, W. Va.	Dead-burned
Philip Carey Mfg. Co.	Plymouth Meeting, Pa.	Conshohocken, Pa.	Magnesia
Keasbey and Mattison Co.	Butler Ave. and Maple St., Ambler, Pa.	Ambler, Pa.	Magnesia
From seawater bitterns:			
Westvaco Chlorine Products Corporation	405 Lexington Ave., New York, 17, N. Y.	Newark, Cal.	Caustic-calcined, dead-burned
From well brines:			
Michigan Chemical Corporation	500 N. Bankson St., St. Louis, Mich.	St. Louis, Mich.	Caustic-calcined, dead-burned
From raw sea water:			
Northwest Magnesite Co.	1800 Farmers Bank Bldg., Pittsburgh, 22, Pa.	Cape May, N. J.	Dead-burned
Permanente Metals Corporation	Permanente, Cal.	Moss Landing, Cal.	Caustic-calcined
Marine Magnesium Products Corporation	South San Francisco, Cal.	South San Francisco, Cal.	Magnesia

MINERAL EXHIBIT AND STATISTICS

ACCESSIONS TO THE EXHIBIT

By Henry H. Symons *

The museum of the State Division of Mines possesses an exceptionally fine collection of rocks and minerals of economic and academic value. It ranks among the first five such collections in North America and contains not only specimens of most of the known minerals found in California, but much valuable and interesting material from other States and foreign countries as well.

The exhibit is daily visited by engineers, students, business men, and prospectors as well as tourists and sightseers. In addition to its practical use in the economic development of California's mineral resources, the collection is a most valuable educational asset to the State and to San Francisco.

Mineral specimens suitable for exhibit purposes are solicited, and their donation will be appreciated by the Division of Mines, as well as by those who utilize the facilities of the collection.

Among the specimens received recently and catalogued for the exhibit are the following:

21146 Goose Lake Meteorite Fragment (iron). Entire mass in National Museum, Washington, D. C. Found in Modoc Lava Beds a few miles west of Goose Lake, Modoc County, California, on October 13, 1938. Weight 2573 lbs. Dimensions 3 ft. 10 in. by 2 ft. 4½ in. by 1 ft. 8 in. Donated by Smithsonian Institution. Date: December 30, 1943. IN CASE NO. 103.

21147 MAGNESITE from property of Sierra Magnesite Company, Gabbs, Nevada. Donated by Westvaco Chlorine Products Corp., Newark, Calif. Dec. 29, 1943. IN CASE NO. 407.

21148 HEULANDITE and LAUMONTITE (both hydrous calcium silicates) from New Jersey. Donated by Mr. T. Orchard Lisle, 121 Second St., San Francisco, Calif. Date: December 30, 1943. IN CASE NO. 134.

21149 IRON ORE—HEMATITE found in Plumas County about four miles west of Westwood. Donor: R. V. Montgomery, 249 W. Main St., Los Gatos, Calif. Date: December 30, 1943. IN CASE NO. 222.

REVIEW OF CALIFORNIA MINERAL PRODUCTION FOR 1943

By Henry H. Symons *

The total value of the mineral production of California for the year 1943 is conservatively estimated to be $419,536,000. This is partly detailed in the tabulation below, but there are more than 60 mineral substances on California's commercial list. Figures on the most important items only are available at this early date. The production report forms are being mailed to the operators in all mineral lines and the detailed and completed report will be compiled and published later.

* Statistician and Curator, Division of Mines.

The estimated total of $419,536,000 is an increase of approximately $10,798,000 over the 1942 total value of $408,738,434. The principal substance showing increases in total value over the previous year were petroleum, natural gas, copper, quicksilver, tungsten ore, iron ore, chromite, manganese ore, and brick. Decreases in total value in important mineral substances were registered by gold, cement, miscellaneous stone, silver.

The total petroleum output showed an increase of about 36,169,000 barrels or about 14.5 percent in amount and about 20 percent in value over that of 1942. The estimated quantity of crude oil was 383,660,000 barrels for the year. At the end of March there was an increase in the price of all grades of crude oil, which was about an average of 6 cents a barrel. Natural gas showed an increase in both amount and value of that utilized compared with the previous year.

Reports of the Mint and smelters show the output of gold to be the smallest of any year since 1848, which was due to the War Production Board's mine closing order L-208 of October 8, 1942. Practically all other metals, including copper, chromite, lead, iron ore, manganese ore, molybdenum ore, quicksilver, and tungsten ore, showed an increased output during the year, with the exception of silver and platinum metals. The output of copper, chromite, quicksilver, and tungsten ore each exceeded the million dollar mark, as well as that of gold. Of the structural group, only brick and hollow building tile showed an increase in total value. Cement and miscellaneous stone registered marked decreases in both amount and value from 1942. Under the miscellaneous industrial group, there were many increases and decreases in total outputs, with the group as a whole showing a slight increase in total value. The saline group as a whole showed an increase in total value.

The estimated values and quantities for 1943 are as follows:

$5,180,000	(48,000 fine ozs.) gold.
434,000	(610,000 fine ozs.) silver.
2,333,000	(17,950,000 lbs.) copper.
862,000	(11,650,000 lbs.) lead.
424,000	(3,750,000 lbs.) zinc.
16,381,000	other metals, including chromite, iron ore, manganese ore, molybdenum ore, platinum group metals, quicksilver, and tungsten ore.
290,752,000	(283,660,000 barrels) petroleum.
28,076,000	(452,840,000 M. cu. ft.) natural gas.
28,244,000	(18,460,000 barrels) cement.
15,000,000	miscellaneous stone; including crushed rock, sand and gravel.
6,000,000	brick and hollow building tile.
1,150,000	other structural materials including bituminous rock, granite, lime, magnesite, marble, sandstone, and slate.
8,750,000	miscellaneous industrial minerals.
15,950,000	salines, including borates, potash, iodine, salt, soda, and others.
$419,536,000	total value.

LABORATORY

ADDITIONS TO BULLETIN 113

By George L. Gary *

No. 131 **Beyerite**, a new bismuth carbonate of unknown formula, has been found at the Stewart Mine, Pala, San Diego County, as compact masses of a greenish-gray color embedded in massive quartz. It appears to be an alteration product of a primary bismuth mineral in the pegmatite.

No. 132 **Carbon dioxide** (CO_2) occurs on the Beattie Ranch, 6 miles southwest of Hopland, Mendocino County.

---

* Mineral Technologist, Division of Mines.

LIBRARY

LIBRARY REPORT

By James M. Little*

OUTLINE OF REPORT

INTRODUCTION

The library of the Division of Mines contains more than 6,000 selected volumes on mines, mining, and allied subjects. It is also the repository for reports and bulletins of technical departments of Federal and State governments and educational institutions both domestic and foreign. Current copies of newspapers published in the mining centers of the State are also available for reference.

The library and reading room are open to the public during the usual office hours, when the librarian may be freely called upon for all necessary assistance.

PUBLICATIONS OF THE UNITED STATES GEOLOGICAL SURVEY AND UNITED STATES BUREAU OF MINES

The library of the Division of Mines has available for public reference the following publications of the United States Geological Survey: Annual Reports, Monographs, Professional Papers, Bulletins, Water-Supply Papers, Mineral Resources, Folios of the Geologic Atlas of the United States (broken file), Maps with Descriptive Text (broken file), Administrative Publications (broken file); and the following publications of the United States Bureau of Mines: Bulletins, Technical Papers, Economic Papers (broken file), Mineral Resources of the United States, Monographs (broken file), Reports of Investigations, Information Circulars.

Reports, mainly on California, recently received from the Survey and Bureau of Mines include:

United States Geological Survey

Bulletins

939-C-D. Geophysical Abstracts, July-December, 1942.
940-A. The Rose Creek Tungsten Mine, Pershing County, Nevada, 1943.
940-C. Geophysical Surveys in the Ochoco Quicksilver District, Oregon, 1943.
936-Q. The Coso Quicksilver District, Inyo County, Calif., 1943.

* Librarian, Division of Mines.

Water-Supply Papers

941 Water Levels and Artesian Pressure in Observation Wells in the United States in 1941, Part 6, Southwestern States and Territory of Hawaii, 1943.
942 Quality of Surface Waters of the United States.
959 Surface Water Supply of the United States, 1942, Part 9, Colorado River Basin, 1942.
961 Surface Water Supply of the United States, 1942, Part 11, Pacific Slope Basins in California, 1943.

Topographic Maps

Arroyo Grande Quadrangle, San Luis Obispo County, 1942, scale 1:62500.
Blairsden Quadrangle, Plumas County, 1943, scale 1:62500.
Branch Mountain Quadrangle, San Luis Obispo and Santa Barbara Counties, 1942, scale 1:62500.
Cayucos Quadrangle, San Luis Obispo County, 1943, Scale 1:62500.
Chileno Canyon Quadrangle, Los Angeles County, 1942, scale 1:24000.
Colton Quadrangle, San Bernardino and Riverside Counties, 1943, scale 1:31680.
Corona and Vicinity, Riverside and San Bernardino Counties, 1942, scale 1:31680.
Del Mar Quadrangle, San Diego County, 1943, scale 1:31680.
Eureka Quadrangle, Humboldt County, 1942, scale 1:62500.
Ferndale Quadrangle, Humboldt County, 1943, 1:62500.
Fontana Quadrangle, San Bernardino and Riverside Counties, 1943, scale 1:31680.
Jamul Quadrangle, San Diego County, 1943, scale 1:62500.
Joaquin Rocks Quadrangle, Fresno County, 1943, scale 1:62500.
Kramer Quadrangle, Kern, Los Angeles, and San Bernardino Counties, 1942, scale 1:62500.
La Jolla Quadrangle, San Diego County, 1943, scale 1:31680.
Lodoga Quadrangle, Glenn and Colusa Counties, 1943, scale 1:62500.
Mt. Gleason Quadrangle, Los Angeles County, 1942, scale 1:24000.
New Idria Quadrangle, San Mateo and Fresno Counties, 1943, scale 1:62500.
Ortigalita Peak Quadrangle, Merced and Fresno Counties, 1943, scale 1:62500.
Point Loma Quadrangle, San Diego County, 1942, scale 1:31680.
Poway Valley Quadrangle, San Diego County, 1942, scale 1:31680.
Redlands and Vicinity, San Bernardino County, 1943, scale 1:31680.
Riverside and Vicinity, Riverside County, 1942, scale 1:31680.
Rogers Lake Quadrangle, Kern and Los Angeles Counties, 1942, scale 1:62500.
San Ardo Quadrangle, Monterey and San Benito Counties, 1943, scale 1:62500.
San Luis Obispo Quadrangle, San Luis Obispo County, 1942, scale 1:62500.
San Pedro Hill Quadrangle, Los Angeles County, 1942, scale 1:24000.
San Ysidro Quadrangle, San Diego County, 1943, scale 1:31680.
Sebastopol Quadrangle, Sonoma and Marin Counties, 1942, scale 1:62500.
Shadow Mountains Quadrangle, Los Angeles and San Bernardino Counties, 1942, scale 1:62500.
Sunland Quadrangle, Los Angeles County, 1942, scale 1:24000.
Tobias Peak Quadrangle, eastern half, Tulare and Kern Counties, 1943, scale 1:125000.

Professional Papers

197-D The Basin and Range Province in Utah, Nevada and California, 1943.
197-E Some Standard Thermal Dehydration Curves of Minerals, 1943.
200 Geology and Ore Deposits of the Magdalena Mining District, New Mexico, 1942.

United States Bureau of Mines

Bulletins

442 Seismic Effects of Quarry Blasting, 1942.
445 Plastic and Swelling Properties of Bituminous Coking Coals, 1942.
446 Typical Analyses of Coals of the United States, 1942.
451 Syllabus of Clay Testing, Part 1, 1943.

Technical Papers

642 Hydrogenation and Liquefaction of Coal, Part 2, 1942.
643 Theoretical Calculations for Explosives, II, Explosion Pressures.
646 Hydrogenation and Liquefaction of Coal, Part 3, 1942.
648 Mineral Matter in Coal, 1942.
654 Hydrogenation and Liquefaction of Coal, Part 4, 1943.

Reports of Investigations

No. 3683, 3684, 3685, 3686, 3687, 3688, 3689, 3690, 3693, 3694, 3695, 3696, 3699, 3700, 3704, 3705, 3706, 3707, 3708, 3710, 3712, 3713, 3714, 3715, 3716, 3717, 3718, 3719, 3720, 3721, 3722, 3723, 3724, 3725, 3726, 3727, 3728, 3730, 3731, 3732, 3733, 3735, 3736, 3737, 3739, 3740, 3741, 3742, 3743, 3744, 3745, 3746, 3748.

Information Circulars

No. 7235, 7236, 7237, 7241, 7242, 7243, 7244, 7245, 7246, 7247, 7248, 7249, 7250, 7251, 7252, 7253, 7254, 7255, 7256, 7257, 7258, 7259, 7260, 7261, 7262, 7263, 7264, 7265, 7266, 7267, 7268, 7269, 7270, 7271, 7272, 7274.

PUBLICATIONS OF STATE SURVEYS

A broken file of mining and geological publications, issued by the organizations listed below, may be consulted in the library of the Division of Mines.

Alabama Geological Survey, University.
Alaska (Territorial Commissioner of Mines), Juneau.
Arizona Bureau of Mines, Tucson.
Arkansas Geological Survey, Little Rock.
Colorado Bureau of Mines, Denver.
Connecticut Geological and Natural History Survey, Hartford.
Florida Department of Conservation, Tallahassee.
Georgia Division of Geology, Atlanta.
Idaho Bureau of Mines and Geology, Moscow.
Illinois Geological Survey, Urbana.
Indiana Division of Geology, Indianapolis.
Iowa Geological Survey, Des Moines.
State Geological Survey of Kansas, Lawrence.
Kentucky Geological Survey, Frankfort.
Louisiana Department of Conservation, New Orleans.
Maine State Geologist, Augusta.
Maryland Geological Survey, Baltimore.
Michigan Geological Survey, Lansing.
Minnesota Geological Survey, Minneapolis.
Mississippi State Geological Survey, University.
Missouri Bureau of Geology and Mines, Rolla.
Montana Bureau of Mines and Geology, Butte.
Nebraska Geological Survey, Lincoln.
Nevada State Bureau of Mines, Reno.
New Jersey Department of Conservation and Development, Trenton.
New Mexico Bureau of Mines and Mineral Resources, Socorro.
New York Science Division, Albany.
North Carolina Geological and Economic Survey, Chapel Hill.
North Dakota Geological Survey, Grand Forks.
Ohio Geological Survey, Columbus.
Oklahoma Geological Survey, Norman.
Oregon State Department of Geology and Mineral Industries, Portland.
Pennsylvania Topographic and Geological Survey, Harrisburg.
South Dakota State Geological Survey, Vermillion.
Tennessee Division of Geology, Nashville.
Texas Bureau of Economic Geology, Austin.
Virginia Geological Survey, University.
Washington State Department of Conservation and Development, Pullman.
West Virginia Geological Survey, Morgantown.
Wisconsin Geological and Natural History Survey, Madison.
Wyoming Geological Survey, Cheyenne.

PUBLICATIONS OF FOREIGN GOVERNMENTS

Publications of the following departments of foreign governments are received and current issues may be consulted in the library. Earlier issues of foreign-language publications have been loaned to the California Academy of Sciences in Golden Gate Park, because of the limited storage space at the Division's offices in the Ferry Building. They may, however, be consulted at the Academy.

Alberta Research Council, Edmonton.
Argentina Direccion General de Minas y Geologica, Buenos Aires.
British Columbia Minister of Mines, Victoria.
British Museum of Natural History, London.
Canada Department of Mines, Ottawa.
Cuerpo de Ingenieros de Minas y Aguas del Peru, Lima.
Departmento de Minas y Petroleo, Mexico City, Mexico.
Geological Service of Minas Geraes, Bella Horizonte, Brazil.
Geological Survey of Scotland.
Instituto Historica e Geographico Rio de Janeiro.
Museo de Historia Natural de Montevideo, Uruguay.
New South Wales Department of Mines, Sydney, Australia.
New Zealand Geological Survey Branch, Wellington.
Nova Scotia Department of Public Works and Mines, Halifax.
Ontario Department of Mines, Toronto, Canada.
Quebec Bureau of Mines, Quebec.
Queensland Department of Mines, Brisbane, Australia.
South Australia Department of Mines, Adelaide.
Transvaal Chamber of Mines, Johannesburg, South Africa.
Western Australia Geological Survey, Perth.

PUBLICATIONS OF FOREIGN AND DOMESTIC SOCIETIES AND EDUCATIONAL INSTITUTIONS

Academia de Ciencias y Artes de Barcelona, Spain.
Academy of Natural Sciences of Philadelphia.
American Association of Petroleum Geologists, Tulsa, Oklahoma.
American Geographical Society of New York.
American Institute of Mining and Metallurgical Engineers, New York.
American Journal of Science, New Haven, Conn.
American Philosophical Society, Philadelphia.
Australian Museum, Sydney.
California Academy of Sciences, San Francisco.
Canadian Institute of Mining and Metallurgy, Montreal.
Carnegie Institute of Washington.
Cleveland Museum of Natural History, Cleveland, Ohio.
Colorado College Publications, Colorado Springs.
Colorado Scientific Society, Denver.
Commonwealth Club, San Francisco.
Economic Geology, Lancaster, Pa.
Field Museum of Natural History, Chicago.
Franklin Institute of the State of Pennsylvania, Lancaster.
Geological Society of America, Columbia University, New York.
Geological Society of London.
Institution of Mining and Metallurgy, London.
Instituto Geologico de Mexico, Mexico, D. F.
Journal of Geology, Chicago.
Mineralogical Society of America, Menasha, Wisconsin.
Michigan College of Mining and Technology, Houghton.
Mining and Metallurgical Society of America, New York.
Missouri School of Mines and Metallurgy, Rolla.
Museu Nacional, Rio de Janeiro.
National Research Council, Washington, D. C.
New York Academy of Sciences, New York.
New York State Museum, Albany.
Pennsylvania State College, State College.
Philippine Journal of Science, Manila.
Royal Society of South Australia, Adelaide.
Seismological Society of America, Stanford University.
Sierra Club, San Francisco.
Society of Economic Paleontologists and Mineralogists, Fort Worth, Texas.
Southern California Academy of Sciences, Los Angeles.
Stanford University, Palo Alto, California.
University of California Publications in Engineering, Geography, and Geology, Berkeley.
University of Harvard, Department of Mineralogy and Petrography, Cambridge, Mass.

CURRENT MAGAZINES

Current issues of the technical magazines listed below are on file in the reading room of the library, and may be consulted.

Asbestos, Philadelphia, Pennsylvania.
Brick and Clay Record, Chicago.
California Magazine of the Pacific, San Francisco.
California Mining Journal, Auburn.
California Oil World, Los Angeles.
California Safety News, San Francisco.
Canadian Mining Journal, Gardenvale, Quebec.
Chemical and Metallurgical Engineering, New York City.
Chemical Engineering and Mining Review, Melbourne, Australia.
Civil Engineering, New York City.
Colorado School of Mines, Golden, Colorado.
Engineering and Mining Journal, New York City.
Fusion Facts, Whittier, California.
Gold, Toronto, Canada.
Grizzly Bear, Los Angeles.
Hercules Mixer, Wilmington, Delaware.
Independent Monthly, Tulsa, Oklahoma.
Lubrication, The Texas Co., New York City.
Metals and Alloys, Pittsburgh, Pennsylvania.
Mining and Contracting Review, Salt Lake City.
Mineralogist, Portland, Oregon.
Mining Congress Journal, Washington, D. C.
Mining and Industrial News, San Francisco.
Mining and Geological Journal, Melbourne, Victoria, Australia.
Mining Journal, London.
Mining Journal, Phoenix, Arizona.
Mining and Metallurgy, New York City.
Mining World, Seattle.
Nickel Steel Topics, New York City.
Northwest Mining News, Spokane, Washington.

Oil and Gas Journal, Tulsa, Oklahoma.
Oil, Paint and Drug Reporter, New York City.
Oil Weekly, Houston, Texas.
Pacific Purchaser, San Francisco.
Petroleum World, Los Angeles.
Queensland Government Mining Journal, Brisbane, Australia.
Rock Products, Chicago.
Rocks and Minerals, Peekskill, New York.
Scientific American, New York City.
Southwest Builder and Contractor, Los Angeles.
Standard Oil Bulletin, San Francisco.
Stone, New York City.
Western Mining News, San Francisco.

NEWSPAPERS

Current issues of the following papers are received and kept on file in the library:

Alaska Weekly, Seattle, Washington.
Amador Dispatch, Jackson, California.
Banner, Sonora, California.
Barstow Printer, Barstow, California.
Bridgeport Chronicle-Union, Bridgeport, California.
Calaveras Californian, Angels Camp, California.
Calaveras Prospect, San Andreas, California.
Daily Commercial News, San Francisco, California.
Del Norte Triplicate, Crescent City, California.
Denver Mining Record, Denver, Colorado.
Inyo Independent, Independence, California.
Inyo Register, Bishop, California.
Las Vegas Age, Las Vegas, Nevada.
Livermore Herald, Livermore, California.
Los Angeles Times, Los Angeles, California.
Mariposa Gazette, Mariposa, California.
Mining Press, Reno, Nevada.
Mohave Miner, Kingman, Arizona.
Morning Union, Grass Valley, California.
Mountain Messenger, Downieville, California.
Needles Nugget, Needles, California.
Oroville Mercury Register.
Placer Herald, Auburn, California.
Placerville Times, Placerville, California.
Plumas Independent, Quincy, California.
Randsburg Times, Randsburg, California.
Tehachapi News, Tehachapi, California.
Terra Bella News, Terra Bella, California.
Tuolumne Independent, Sonora, California.
Tuolumne Prospector, Tuolumne, California.
Union Democrat, Sonora, California.
Weekly Trinity Journal, Weaverville, California.
Yreka Journal, Yreka, California.

NEW BOOKS

Recent accessions to the library are the following books:

Agg, T. R. and Foster, W. L., The Preparation of Engineering Reports, 192 pp., New York, McGraw-Hill Book Co., 1935. (F. W. Bradley Memorial Book Fund.)

American Society for Testing Materials, A.S.T.M. Standards on Cement, 119 pages, Phila., Am. Soc. for Test. Mat., 1942. (John Hays Hammond Library.)

American Society for Testing Materials, A.S.T.M. Methods of Chemical Analysis of Metals, 323 pp., Phila., Am. Soc. for Test. Mat., 1943. (John Hays Hammond Public Mining Library.)

American Society for Testing Materials, Index to A.S.T.M. Standards, 197 pp., Phila., Am. Soc. for Test. Mat., 1943. (John Hays Hammond Library.)

American Society for Testing Materials, Symposium on Lime, 117 pp., Phila., Am. Soc. for Test. Mat., 1939, (John Hays Hammond Library.)

American Society for Testing Materials, A.S.T.M. Standards on Mineral Aggregates, 126 pp., Phila., Am. Soc. for Test. Mat., 1942. (John Hays Hammond Library.)

American Society for Testing Materials, Symposium on the Outdoor Weathering of Metals and Metallic Coatings, 113 pp., Phila., Am. Soc. for Test. Mat., 1934. (John Hays Hammond Library.)

American Society for Testing Materials, A.S.T.M. Standards on Petroleum Products and Lubricants, 442 pp., Phila., Am. Soc. for Test. Mat. 1943. (John Hays Hammond Library.)

American Society for Testing Materials, Symposium on Powder Metallurgy, 55 pp., Phila., Am. Soc. for Test. Mat., 1943. (John Hays Hammond Library.)

American Society for Testing Materials, A.S.T.M. Standards on Refractory Materials, 201 pp., Phila., Am. Soc. for Test. Mat., 1943. (John Hays Hammond Library.)

Baeza, W. J., Powder Metallurgy. 212 pp., New York. Reinhold Publishing Co., 1943. (F. W. Bradley Memorial Book Fund.)

Bateman, A. M., Economic Mineral Deposits, 898 pp., New York, John Wiley & Sons.

Climax Molybdenum Company, Molybdenum in Steel, New York, Climax Molybdenum Co.

Davis, D. H., The Earth and Man, 675 pp., New York, The Macmillan Co., 1942.

The Engineering Index, 1942, 1262 pp., New York, Engineering Index, Inc.

Hoyt, S. L., Metals and Alloys Data Book, 334 pp., New York, Reinhold Publishing Co., 1943. (F. W. Bradley Memorial Book Fund.)

Kraus, E. H., Hunt, W. F., and **Ramsdell, L. S.,** Mineralogy, 3d edition, 638 pp., New York, McGraw-Hill Book Co.

Li, K. C. and **Wang, C. Y.,** Tungsten, American Chemical Society Series of Scientific and Technologic Monographs, No. 94, 325 pp., New York, Reinhold Publishing Co., 1943. (F. W. Bradley Memorial Book Fund.)

Lindquist, O. V., Blast Hole Diamond Drilling, 54 pp., New York, J. K. Smit & Sons, 1944.

Merck & Co., Inc., The Merck Index, Fifth Edition, 1062 pp., Rahway, N. J., Merck & Co., Inc., 1940.

Mines Register, 1942, V. XXI, 740 pp., New York, Atlas Publishing Co., 1942.

New York World-Telegram, The World Almanac, 912 pp., 1944. (F. W. Bradley Memorial Book Fund.)

Petroleum World, Annual Review 1942-1943, 200 pp., Los Angeles, Petroleum World, 1943.

Pratt, W. E., Oil in the Earth, 110 pp., Lawrence, Kan., University of Kansas Press, 1943.

Schuchert, C., Stratigraphy of the Eastern and Central United States, 1013 pp., New York, John Wiley & Sons, 1943.

Scott, W. W., Elements of Qualitative Chemical Analysis, 166 pp., New York, D. Van Nostrand Co., 1932.

Talley, B. B., Engineering Applications of Aerial and Terrestrial Photogrammetry, 612 pp., New York, Pitman Publishing Co., 1938. (F. W. Bradley Memorial Book Fund.)

SERVICES OF THE DIVISION OF MINES

The Division of Mines (formerly State Mining Bureau) is maintained for the purpose of assisting in all possible ways in the development of California's mineral resources.

As one means of offering tangible service to the mining public, the State Mineralogist for many years has issued an annual or a biennial report reviewing in detail the mines and mineral deposits of the various counties.

As a progressive step in advancing the interests of the mineral industry, and as permitting earlier distribution to the public, publication of the Annual Report of the State Mineralogist in the form of monthly chapters was begun in January 1922, and continued until March 1923. Owing to a lack of funds for printing this was changed to a quarterly publication, beginning in September 1923. For the same reason, beginning with the January 1924 issue, it became necessary to charge a subscription price. This covers approximately the cost of printing.

Pages are numbered consecutively throughout the year and an index to the complete report is included annually in the closing number.

Beginning with the 1930 issues, the activities and progress of the Geologic Branch are recorded also in these quarterly chapters. The important part that geology plays in the economic development of our mineral resources is further recognized in the change of title from *Mining in California* to CALIFORNIA JOURNAL OF MINES AND GEOLOGY, beginning with the January 1933 chapter.

While current activities of all descriptions are covered in these chapters, the practice of issuing from time to time technical reports on special subjects will be continued as well. A list of such reports now available is appended hereto, and the names of new bulletins will be added in the future as they are completed.

The chapters are subject to revision, correction and improvement. Constructive suggestions from the mining public will be gladly received, and are invited.

The one aim of the Division of Mines is to increase its usefulness and to stimulate the intelligent development of the wonderful, latent resources of the State of California.

TYPES OF REPORTS

In general the reports presented in these chapters are grouped into three classes:

1. Mines and mineral resources of a given county or area (describing kind, character, distribution and extent of development).

2. Specific economic and industrial mineral products (listing and describing the resources over the entire State of a given mineral substance, e.g., feldspar).

3. Geological reports on specific areas (recording results and conclusions with maps, derived from field studies; and tied in with economic possibilities and developments).

Reports of District Mining Engineers

In 1919-1920 the Mining Bureau was organized into four main geographical divisions, with the field work delegated to a mining engineer in each district, working out from field offices that were established in Redding, Auburn, San Francisco and Los Angeles, respectively. This move brought the office into closer personal contact with operators, and it has many advantages over former methods of conducting field work, including lower traveling-expense bills for the Bureau's engineers. In 1923 the Redding and Auburn field offices were consolidated and moved to Sacramento.

The Redding office was reestablished in 1928, and the boundaries of each district adjusted. The counties now included in each of the four divisions and the locations of the branch offices are shown on the frontispiece outline map of the State.

Reports of mining activities and development in each district, prepared by the District Engineer, will continue to appear under the proper field division heading.

Special Articles

Detailed technical reports on special subjects, the result of research work or extended field investigations, will continue to be issued as separate bulletins by the Division, as has been the custom in the past.

Shorter and less elaborate technical papers and articles by members of the staff and others are published in each number of *California Journal of Mines and Geology.*

These special articles cover a wide range of subjects both of historical and current interest; descriptions of new processes, or metallurgical and industrial plants, new mineral occurrences, and interesting geological formations, as well as articles intended to supply practical and timely information on the problems of the prospector and miner, such as the text of new laws and official regulations and notices affecting the mineral industry.

MAIL AND FILES

The Division of Mines maintains, in addition to its correspondence files and the library, a mine file which includes original reports on the various mines and mineral properties of all kinds in California.

During each quarterly period there are several thousand letters received and answered at the San Francisco office alone, covering almost every phase of prospecting, mining and developing mineral deposits, reduction problems, marketing of refined products and mining law. In addition to this, hundreds of oral questions are answered daily, both at the main office and the district offices, for the many inquirers who come in for personal interviews and to consult the files and library.

COMMERCIAL MINERAL NOTES

The producer and consumer of mineral products are mutually dependent upon each other for their prosperity, and one of the most direct aids rendered by this Division to the mining industry in the past has been that of bringing producers and consumers into direct touch with each other.

This work has been carried on largely by correspondence, supplemented by personal consultation. Lists of buyers of all the commercial

minerals produced in California have been made available to producers upon request, and likewise the owners of undeveloped deposits of various minerals, and producers of them, have been made known to those looking for raw mineral products.

When the publication of *Mining in California* was on a monthly basis, current inquiries from buyers and sellers were summarized and lists of mineral products or deposits 'wanted' or 'for sale' included in each issue.

It is important that inquiries of this nature reach the mining public as soon as possible and in order to avoid the delay incident to the present quarterly publication of *California Journal of Mines and Geology,* these lists are now issued monthly in the form of a mimeographed sheet under the title of *Commercial Mineral Notes,* and sent to those on the mailing list of *California Journal of Mines and Geology.*

EMPLOYMENT SERVICE

Following the establishment of the Mining Division branch offices in 1919, a free technical employment service was offered as a mutual aid to mine operators and technical men for the general benefit of the mineral industry.

Briefly summarized, men desiring positions are registered, the cards containing an outline of the applicant's qualifications, position wanted, salary desired, etc., and as notices of 'positions open' are received, the names and addresses of all applicants deemed qualified are sent to the prospective employer for direct negotiations.

Telephone and telegraphic communications are also given immediate attention.

Technical men, or those qualified for supervisory positions, and vacancies of like nature only, are registered, as no attempt will be made to supply mine and mill labor.

Registration cards for the use of both prospective employers and employees may be obtained upon request, and a cordial invitation is extended to the industry to make free use of the facilities afforded. Parties interested should communicate direct with our San Francisco office.

DETERMINATION OF MINERAL SAMPLES

Samples (limited to two at one time) of any mineral found in the State may be sent to the Division of Mines for identification, and the same will be classified free of charge. No samples will be determined if received from points outside the State. It must be understood that no assays, or quantitative determinations will be made. Samples should be in lump form if possible, and marked plainly with name of sender on outside of package, etc. No samples will be received unless delivery charges are prepaid. A letter should accompany sample, giving locality where mineral was found and the nature of the information desired.

11—33963

PUBLICATIONS OF THE DIVISION OF MINES

During the past sixty-three years, in carrying out the provisions of the organic act creating the former California State Mining Bureau, there have been published many reports, bulletins and maps which go to make up a library of detailed information on the mineral industry of the State, a large part of which could not be duplicated from any other source.

One feature that has added to the popularity of the publications is that many of them have been distributed without cost to the public, and even the more elaborate ones have been sold at a price which barely covers the cost of printing.

Owing to the fact that funds for advancing the work of this department have usually been limited, the reports and bulletins mentioned are printed in limited editions many of which are now entirely exhausted.

Copies of such publications are available for reference, however, in the offices of the Division of Mines, in the Ferry Building, San Francisco; State Building, Los Angeles; State Office Building, Sacramento; Redding; and Division of Oil and Gas at Santa Barbara, Santa Paula, Taft, Bakersfield, Coalinga. They may also be found in many public, private and technical libraries in California and other states and foreign countries.

A catalog of all publications from 1880 to 1917, giving a synopsis of their contents, is issued as Bulletin No. 77.

Publications in stock may be obtained postpaid by addressing the San Francisco, Los Angeles or Sacramento offices and enclosing the requisite amount.

Remittances of stamps in an amount not to exceed 26 cents, currency or coin will be accepted at sender's risk. Payment is preferred in the form of money orders.

Money orders should be made payable to the Division of Mines.

Write for latest revised price list.

NOTE.—The Division of Mines frequently receives requests for some of the early Reports and Bulletins now out of print, and it will be appreciated if parties having such publications and wishing to dispose of them will advise this office.

REPORTS

Asterisks (**) indicate the publication is out of print.	Price (including postage and sales tax)
**First Annual Report of the State Mineralogist, 1880, 43 pp. Henry G. Hanks	----
**Second Annual Report of the State Mineralogist, 1882, 514 pp., 4 illustrations, 1 map. Henry G. Hanks	----
**Third Annual Report of the State Mineralogist, 1883, 111 pp., 21 illustrations. Henry G. Hanks	----
**Fourth Annual Report of the State Mineralogist, 1884, 410 pp., 7 illustrations. Henry G. Hanks	----
**Fifth Annual Report of the State Mineralogist, 1885, 234 pp., 15 illustrations, 1 geological map. Henry G. Hanks	----
Sixth Annual Report of the State Mineralogist, Part I, 1886, 145 pp., 3 illustrations, 1 map. Henry G. Hanks Price $0.75, sales tax $0.02	$0.77
Part II, 1887, 222 pp., 36 illustrations. William Irelan, Jr. Price $0.75, sales tax $0.02	.77
**Seventh Annual Report of the State Mineralogist, 1887, 315 pp. William Irelan, Jr.	----
**Eighth Annual Report of the State Mineralogist, 1888, 948 pp., 122 illustrations. William Irelan, Jr.	----
**Ninth Annual Report of the State Mineralogist, 1889, 352 pp., 57 illustrations, 2 maps. William Irelan, Jr.	----
**Tenth Annual Report of the State Mineralogist, 1890, 983 pp., 179 illustrations, 10 maps. William Irelan, Jr.	----
Eleventh Report (First Biennial) of the State Mineralogist, for the two years ending September 15, 1892, 612 pp., 73 illustrations, 4 maps. William Irelan, Jr. Price $1.50, sales tax $0.04	1.54
**Twelfth Report (Second Biennial) of the State Mineralogist, for the two years ending September 15, 1894, 541 pp., 101 illustrations, 5 maps. J. J. Crawford	----
**Thirteenth Report (Third Biennial) of the State Mineralogist, for the two years ending September 15, 1896, 726 pp., 93 illustrations, 1 map. J. J. Crawford	----
Chapters of the State Mineralogist's Report, XIV Biennial Period, 1913, 1914, Fletcher Hamilton:	
**Mines and Mineral Resources, Amador, Calaveras and Tuolumne Counties, 172 pp., paper	----
Mines and Mineral Resources, Colusa, Glenn, Lake, Marin, Napa, Solano, Sonoma and Yolo Counties, 208 pp., paper Price $0.50, sales tax $0.01	.51
**Mines and Mineral Resources, Del Norte, Humboldt and Mendocino Counties, 59 pp., paper	----
**Mines and Mineral Resources, Fresno, Kern, Kings, Madera, Mariposa, Merced, San Joaquin and Stanislaus Counties, 220 pp., paper	----
**Mines and Mineral Resources of Imperial and San Diego Counties, 113 pp., paper	----
**Mines and Mineral Resources, Shasta, Siskiyou and Trinity Counties, 180 pp., paper	----
**Fourteenth Report of the State Mineralogist, for the Biennial Period 1913-1914, Fletcher Hamilton, 1915: A General Report on the Mines and Mineral Resources of Amador, Calaveras, Tuolumne, Colusa, Glenn, Lake, Marin, Napa, Solano, Sonoma, Yolo, Del Norte, Humboldt, Mendocino, Fresno, Kern, Kings, Madera, Mariposa, Merced, San Joaquin, Stanislaus, San Diego, Imperial, Shasta, Siskiyou and Trinity Counties, 974 pp., 275 illustrations, cloth	----
Chapters of the State Mineralogist's Report, XV Biennial Period, 1915-1916, Fletcher Hamilton:	
**Mines and Mineral Resources, Alpine, Inyo and Mono Counties, 176 pp., paper	----
Mines and Mineral Resources, Butte, Lassen, Modoc, Sutter and Tehama Counties, 91 pp., paper Price $0.50, sales tax $0.01	.51

REPORTS—Continued

Asterisks (**) indicate the publication is out of print.

	Price (including postage and sales tax)
Mines and Mineral Resources, El Dorado, Placer, Sacramento and Yuba Counties, 198 pp., paper ---- Price $0.75, sales tax $0.02	$0.77
Mines and Mineral Resources, Monterey, San Benito, San Luis Obispo, Santa Barbara and Ventura Counties, 183 pp., paper ---- Price $0.75, sales tax $0.02	.77
**Mines and Mineral Resources, Los Angeles, Orange and Riverside Counties, 136 pp., paper ----	----
**Mines and Mineral Resources, San Bernardino and Tulare Counties, 186 pp., paper ----	----
**Fifteenth Report of the State Mineralogist, for the Biennial Period 1915-1916, Fletcher Hamilton, 1917: A General Report on the Mines and Mineral Resources of Alpine, Inyo, Mono, Butte, Lassen, Modoc, Sutter, Tehama, Placer, Sacramento, Yuba, Los Angeles, Orange, Riverside, San Benito, San Luis Obispo, Santa Barbara, Ventura, San Bernardino and Tulare Counties, 990 pp., 413 illustrations, cloth ----	----
Chapters of the State Geologist's Report XVI, Biennial Period, 1917-1918, Fletcher Hamilton:	
Mines and Mineral Resources of Nevada County, 270 pp., paper ---- Price $1.00, sales tax $0.03	1.03
Mines and Mineral Resources of Plumas County, 188 pp., paper ---- Price $0.50, sales tax $0.01	.51
Mines and Mineral Resources of Sierra County, 144 pp., paper ---- Price $0.75, sales tax $0.02	.77
Seventeenth Report of the State Mineralogist, 1920, 'Mining in California during 1920,' Fletcher Hamilton; 562 pp., 71 illustrations, cloth ---- Price $2.50, sales tax $0.06	2.56
Eighteenth Report of the State Mineralogist, 1922, 'Mining in California,' Fletcher Hamilton. Chapters published monthly beginning with January, 1922:	
**January, **February, **March, **April, May, June, July, August, September, October, November, December, 1922 ---- Price $0.30, sales tax $0.01	.31
Chapters of Nineteenth Report of the State Mineralogist, 'Mining in California,' Fletcher Hamilton and Lloyd L. Root. January, February, March, September, 1923 ---- Price $0.30, sales tax $0.01	.31
Chapters of Twentieth Report of the State Mineralogist, 'Mining in California,' Lloyd L. Root. Published quarterly. January, April, July, October, 1924, per copy ---- Price $0.30, sales tax $0.01	.31
Chapters of Twenty-first Report of the State Mineralogist, 'Mining in California,' Lloyd L. Root. Published quarterly:	
January, 1925, Mines and Mineral Resources of Sacramento, Monterey and Orange Counties ---- Price $0.30, sales tax $0.01	.31
April, 1925, Mines and Mineral Resources of Calaveras, Merced, San Joaquin, Stanislaus and Ventura Counties ---- Price $0.30, sales tax $0.01	.31
**July, 1925, Mines and Mineral Resources of Del Norte, Humboldt and San Diego Counties ----	----
**October, 1925, Mines and Mineral Resources of Siskiyou, San Luis Obispo and Santa Barbara Counties ----	----
Chapters of Twenty-second Report of the State Mineralogist, 'Mining in California,' Lloyd L. Root. Published quarterly:	
**January, 1926, Mines and Mineral Resources of Trinity and Santa Cruz Counties ----	----
April, 1926, Mines and Mineral Resources of Shasta, San Benito and Imperial Counties ---- Price $0.30, sales tax $0.01	.31
July, 1926, Mines and Mineral Resources of Marin and Sonoma Counties Price $0.30, sales tax $0.01	.31
**October, 1926, Mines and Mineral Resources of El Dorado and Inyo Counties, also report on Minaret District, Madera County ----	----

REPORTS—Continued

Asterisks (**) indicate the publication is out of print.	Price (including postage and sales tax)
Chapters of Twenty-third Report of the State Mineralogist, 'Mining in California,' Lloyd L. Root. Published quarterly:	
January, 1927, Mines and Mineral Resources of Contra Costa County; Santa Catalina Island — Price $0.30, sales tax $0.01	$0.31
April, 1927, Mines and Mineral Resources of Amador and Solano Counties — Price $0.30, sales tax $0.01	.31
**July, 1927, Mines and Mineral Resources of Placer and Los Angeles Counties	----
October, 1927, Mines and Mineral Resources of Mono County — Price $0.30, sales tax $0.01	.31
Chapters of Twenty-fourth Report of the State Mineralogist, 'Mining in California,' Lloyd L. Root. Published quarterly:	
January, 1928, Mines and Mineral Resources of Tuolumne County — Price $0.30, sales tax $0.01	.31
April, 1928, Mines and Mineral Resources of Mariposa County — Price $0.30, sales tax $0.01	.31
**July, 1928, Mines and Mineral Resources of Butte and Tehama Counties	----
October, 1928, Mines and Mineral Resources of Plumas and Madera Counties — Price $0.30, sales tax $0.01	.31
Chapters of Twenty-fifth Report of the State Mineralogist, 'Mining in California,' Walter W. Bradley. Published quarterly:	
**January, 1929, Mines and Mineral Resources of Lassen, Modoc and Kern Counties; also on Special Placer Machines	----
**April, 1929, Mines and Mineral Resources of Sierra, Napa, San Francisco and San Mateo Counties	----
July, 1929, Mines and Mineral Resources of Colusa, Fresno and Lake Counties — Price $0.30, sales tax $0.01	.31
October, 1929, Mines and Mineral Resources of Glenn, Alameda, Mendocino and Riverside Counties — Price $0.30, sales tax $0.01	.31
Chapters of Twenty-sixth Report of the State Mineralogist, 'Mining in California,' Walter W. Bradley. Published quarterly:	
January, 1930, Mines and Mineral Resources of Santa Clara County; also Barite in California — Price $0.40, sales tax $0.01	.41
**April, 1930, Mines and Mineral Resources of Nevada County; also Mineral Paint Materials in California	----
**July, 1930, Mines and Mineral Resources of Yuba and San Bernardino Counties; also Commercial Grinding Plants in California	----
October, 1930, Mines and Mineral Resources of Butte, Kings and Tulare Counties; also Geology of Southwestern Mono County (Preliminary) — Price $0.40, sales tax $0.01	.41
Chapters of Twenty-seventh Report of the State Mineralogist, 'Mining in California,' Walter W. Bradley. Published quarterly:	
January, 1931. Preliminary Report of Economic Geology of the Shasta Quadrangle. Beryllium and Beryl. The New Tariff and Nonmetallic Products. Crystalline Talc. Decorative Effects in Concrete — Price $0.40, sales tax $0.01	.41
April, 1931, Stratigraphy of the Kreyenhagen Shale. Diatoms and Silicoflagellates of the Kreyenhagen Shale. Foraminifera of the Kreyenhagen Shale. Geology of Santa Cruz Island — Price $0.40, sales tax $0.01	.41
**July, 1931. (Yuba, San Bernardino.) Feldspar, Silica, Andalusite and Cyanide Deposits of California. Note on a Deposit of Andalusite in Mono County; its occurrence and chemical importance. Bill creating Trinity and Klamath River Fish and Game District and its effect upon mining	----
October, 1931. (Alpine.) Geology of the San Jacinto Quadrangle south of San Gorgonio Pass, California. Notes on Mining Activities in Inyo and Mono Counties in July, 1931 — Price $0.40, sales tax $0.01	.41
Chapters of Twenty-eighth Report of the State Mineralogist, 'Mining in California,' Walter W. Bradley. Published quarterly:	

REPORTS—Continued

Asterisks (**) indicate the publication is out of print. — Price (including postage and sales tax)

January, 1932, Economic Mineral Deposits of the San Jacinto Quadrangle. Geology and Physical Properties of Building Stone from Carmel Valley. Contributions to the Study of Sediments. Sediments of Monterey Bay. Sanbornite____Price $0.40, sales tax $0.01 — $0.41

**April, 1932. Elementary Placer Mining Methods and Gold Saving Devices. The Pan, Rocker and Sluice Box. Prospecting for Vein Deposits. Bibliography of Placer Mining____ —— ----

**Abstract from April quarterly: Elementary Placer Mining Methods and Gold Saving Devices. Types of Deposits, Simple Equipment. Special Machines. Dry Washing. Black Sand Treatment. Marketing of Products. Placer Mining Areas. Laws. Prospecting for Quartz Veins. Bibliography (mimeographed)

**July-October, (Ventura.) Report accompanying Geologic Map of Northern Sierra Nevada. Fossil Plants in Auriferous Gravels of the Sierra Nevada. Glacial and Associated Stream Deposits of the Sierra Nevada. Jurassic and Cretaceous Divisions in the Knoxville-Shasta Succession of California. Geology of a Part of the Panamint Range. Economic Report of a Part of the Panamint Range. Acquiring Mining Claims Through Tax Title. The Biennial Report of State Mineralogist____ —— ----

Chapters of Report XXIX, 1933 (quarterly): title 'California Journal of Mines and Geology,' containing the following:

- January-April. Gold Deposits of the Redding and Weaverville Quadrangles. Geologic Formations of the Redding-Weaverville District, Northern California. Geology of Portions of Del Norte and Siskiyou Counties. Applications of Geology to Civil Engineering. The Lakes of California. Discovery of Piedmontite in the Sierra Nevada. Tracing 'Buried River' Channel Deposits by Geomagnetic Methods. Geologic Map of Redding-Weaverville District, showing gold mines and prospects. Geologic map showing various mines and prospects of part of Del Norte and Siskiyou Counties____Price $1.00, sales tax $0.03 — 1.03
- July-October. Gold Resources of Kern County. Limestone Deposits of the San Francisco Region. Limestone Weathering and Plant Associations of the San Francisco Region. Booming, Death Valley National Monument, California. Placer Mining Districts, Senate Bill 480. Navigable Waters, Assembly Bill 1543____Price $1.00, sales tax $0.03 — 1.03

Chapters of Report XXX, 1934 (quarterly); titled 'California Journal of Mines and Geology,' containing the following:

- January. Resurrection of Early Surfaces in the Sierra Nevada. Geology and Mineral Resources of Northeastern Madera County. Geology and Mineral Deposits of Laurel and Convict Basins, Southwestern Mono County. Notes on Sampling as Applied to Gold Quartz Deposits____ Price $0.60, sales tax $0.02 — .62
- April-July. Elementary Placer Mining in California and Notes on the Milling of Gold Ores____Price $1.00, sales tax $0.03 — 1.03
- October. Current Mining Developments in Northern California. Current Mining Activity in Southern California. Geology and Mineral Resources of the Julian District, San Diego County. Geology and Mineral Resources of Elizabeth Lake Quadrangle. Dry Placers of Northern Mojave Desert. Biennial Report of State Mineralogist. Assessment Work Within Withdrawn Areas____Price $0.60, sales tax $0.02 — .62

Chapters of Report XXXI, 1935 (quarterly): titled 'California Journal of Mines and Geology,' containing the following:

- January. Review of Gold Mining in East-Central California. 1934. Current Mining Activities in the San Francisco District with Special Reference to Gold. Geological Investigation of the Clays of Riverside and Orange Counties, Southern California. Information regarding Mining Loans by the Reconstruction Finance Corporation____ Price $0.60, sales tax $0.02 — .62
- April. A Geologic Section Across the Southern Peninsular Range of California. New Technique Applicable to the Study of Placers. Grubstake Permits____Price $0.60, sales tax $0.02 — .62

REPORTS—Continued

Asterisks (**) indicate the publication is out of print. | Price (including postage and sales tax)

July. Mines and Mineral Resources of Siskiyou County (with map). Dams for Hydraulic Mining Debris. Leasing System as Applied to Metal Mining. Mine Financing in California. New Laws Make Radical Change in Mining Rights____________Price $0.60, sales tax $0.02 $0.62

October. Mines and Mineral Resources of San Luis Obispo County. Mineral Resources of Portions of Monterey and Kings Counties. Mining Activity at Soledad Mountain and Middle Buttes—Mojave District, Kern County. Geology of a Portion of the Perris Block, Southern California. Mineral Resources of a Portion of the Perris Block, Riverside County___________________________Price $0.60, sales tax $0.02 .62

Chapters of Report XXXII, 1936 (quarterly): titled 'California Journal of Mines and Geology,' containing the following:

January. Gold Mines of Placer County, including Drag-line Dredges. Geologic Report on Borax Lake, California__Price $0.60, sales tax $0.02 .62

April. Geology, Mining and Processing of Diatomite at Lompoc, Santa Barbara County. Essentials in Developing and Financing a Prospect into a Mine. Gold-bearing Veins of Meadow Lake District, Nevada County. Semi-Precious Gem Stone Collection in Division Museum____ Price $0.60, sales tax $0.02 .62

July. Mines and Mineral Resources of Calaveras County. Mining in California by Power Shovel. Assessment Work on Mining Claims Within Withdrawn Areas. Joshua Tree National Monument. Cost of Producing Quicksilver at a California Mine in 1931-1932. The Age of Mineral Utilization_______________________Price $0.60, sales tax $0.02 .62

October. Mineral Resources of Lassen and Modoc Counties. Mechanics of Lone Mountain Landslides, San Francisco. Biennial Report of the State Mineralogist, Properties and Industrial Applications of Opaline Silica_________________________________Price $0.60, sales tax $0.02 .62

Chapters of Report XXXIII, 1937 (quarterly): titled 'California Journal of Mines and Geology,' containing the following:

January. Source Data of the Geologic Map of California, January, 1937. The Geology of Quicksilver Ore Deposits. Prospecting for Lode Gold__ Price $0.60, sales tax $0.02 .62

April. Mineral Resources of Plumas County (with Geologic Map). List of preferred mineral names. New Placer Mining Debris Law________ Price $0.60, sales tax $0.02 .62

July. Mineral Resources of Los Angeles County (with map showing principal Mines and Oil Fields). Geology and mineral deposits of the Western San Gabriel Mountains, Los Angeles County______________ Price $0.60, sales tax $0.02 .62

October. Mineral Resources of the Resting Springs Region, Inyo County. Paleozoic Section in the Nopah and Resting Springs Mountains, Inyo County, California. Native Arsenic from Grass Valley, California____ Price $0.60, sales tax $0.02 .62

Chapters of Report XXXIV, 1938 (quarterly): titled 'California Journal of Mines and Geology,' containing the following:

January. Mineral Development and Mining Activity in Southern California during the year 1937. Doing Something About Earthquakes. Gold and Petroleum in California. Gem Minerals of California, Lapidary Art______________________________Price $0.60, sales tax $0.02 .62

April. Gold Dredging in Shasta, Siskiyou and Trinity Counties; Geology of the Central Santa Monica Mountains; Marketing Mica_____________ Price $0.60, sales tax $0.02 .62

July. El Dorado County, Mineral High-Lights of California; Strategic Minerals of California; Cyanide Treatment of Gossan at Mountain Copper Co.; Submarine Canyons off the California Coast____________ Price $0.60, sales tax $0.02 .62

REPORTS—Continued

Asterisks (**) indicate the publication is out of print. Price (including postage and sales tax)

October, Inyo County, Biennial Report of State Mineralogist, Sulphur Deposits of Inyo County, Geology of the Darwin-Lead Mining District Price $0.60, sales tax $0.02 $0.62

Chapters of Report XXXV, 1939 (quarterly) titled "California Journal of Mines and Geology," containing the following:

January, San Diego County, Geology and Oil Possibilities of Southwestern San Diego Co.; Prospect for 'Minor Metals' and Nonmetallic Minerals; The Right to Mine ---- Price $0.60, sales tax $0.02 .62

April, Shasta County, Public's Interest in Mine Taxation ---- Price $0.60, sales tax $0.02 .62

July, Tertiary Formations of Northern Sacramento Valley, California; Geology and Oil Possibilities of Caliente Range, Cuyama Valley and Carrizo Plain, California; Bibliography of the Geology and Mineral Resources of California for the year 1937; the Giant Goose Lake Meteorite from Modoc County, California -- Price $0.60, sales tax $0.02 .62

**October, Quicksilver Resources of California; Sulphate Minerals of the Leviathan Sulphur Mine, Alpine County, California ---- ----

Reprint of Quicksilver Resources ---- Price $0.50, sales tax $0.02 .52

Chapter of Report XXXVI, 1940 (quarterly) titled "California Journal of Mines and Geology," containing the following:

January Current Mining Activity in Southern California; Notes on Beryl with a Qualitative Analysis for Beryllium; Strategic Minerals Investigations Procedure followed by the U. S. Bureau of Mines ---- Price $0.60, sales tax $0.02 .62

April, Mineral Resources of Mono County; General Geology and Ores of the Blind Spring Hill Mining District, Mono County, California; Short Report on the Geological Formations Encountered in Driving the Mono Craters Tunnel; Methods and Costs of Mining and Concentrating Chromite ---- Price $0.60, sales tax $0.02 .62

July, Economic Mineral Deposits of the Newberry and Ord Mountains, San Bernardino County; Geology of the Newberry and Ord Mountains, San Bernardino County, California; Notes on the Geology of a Portion of the Calico Mountains, San Bernardino County, California; Study of Chrome Process Aided by Martin Dennis Company ---- Price $0.60, sales tax $0.02 .62

October, Mineral Resources of the Kernville Quadrangle; Strategic Problems of the Mineral Industry in California; Descriptive Geology of the Kernville Quadrangle, California; Biennial Report of the State Mineralogist; Strategic Tax Exemption; Federal Loans for Strategic Minerals ---- Price $0.60, sales tax $0.02 .62

Chapters of Report XXXVII, 1941 (quarterly) titled "California Journal of Mines and Geology," containing the following:

January, Mineral Resources of Trinity County; Strategic Minerals Procurement; Geologic Investigation of the Chromite Deposits of California; United States Supreme Court Renders Far-reaching Decision on Power Permits on "Navigable" Streams; Securities and Exchange Commission ---- Price $0.60, sales tax $0.02 .62

April, Tungsten Resources of California; Geological Progress of State Division of Mines; California Earthquakes of Mission Period, 1769-1838 ---- Price $0.60, sales tax $0.02 .62

July, (Nevada County Report and Maps) Mines and Mineral Resources of Nevada County; Price of Gold ---- Price $0.60, sales tax $0.02 .62

October, (Humboldt County) Mineral Resources of Humboldt County; Recent Developments in the Tungsten Resources of California; Tin in California ---- Price $0.60, sales tax $0.02 .62

Chapters of Report XXXVIII, 1942 (quarterly) titled "California Journal of Mines and Geology," containing the following:

January, Mines and Mineral Resources of Sierra County; Chromium ---- Price $0.60, sales tax $0.02 .62

REPORTS—Continued

Asterisks (**) indicate the publication is out of print. — Price (including postage and sales tax)

April, Mineral Resources of Imperial County (report and map); Geology and Mineral Deposits of the Cargo Muchacho Mountains, Imperial County (map and report); Imperial Carbon Dioxide Gas Field; Legendary "White Metal" and Its "Ore"; Mine Assessment Work Suspended on Claims Within Withdrawn Areas — Price $0.60, sales tax $0.02 — $0.62

July-October, Tungsten. Tabulated list of deposits; Economic Mineral Map No. 4—Tungsten; Geology of Ghost Canyon Deposit, Madera County; Geology of Welsh Deposit, Madera County; Geology of Confidence Mining District Deposits, Tuolumne County; Contact-Metamorphic Rocks of Twin Lakes Region, Fresno County; Coso Hot Springs Geology; Biennial Report of State Mineralogist — Price $1.20, sales tax $0.03 — 1.23

Chapters of Report XXXIX, 1943 (quarterly) titled "California Journal of Mines and Geology" containing the following:

January, Mines and Mineral Resources of Santa Cruz County (report and map); Organization and Service of the Division of Mines; Recent Activity in the Strategic Minerals in the San Francisco, Los Angeles, Sacramento, and Redding Field Districts; Department of Interior Information Service — Price $0.60, sales tax $0.02 — .62

Subscription, $2.00 postpaid in advance

BULLETINS

**Bulletin No. 1. Description of Some Desiccated Human Remains, by Winslow Anderson. 1888, 41 pp., 6 illustrations — ----

**Bulletin No. 2. Methods of Mine Timbering, by W. H. Storms. 1894, 58 pp., 75 illustrations — ----

**Bulletin No. 3. Gas and Petroleum Yielding Formations of Central Valley of California, by W. L. Watts. 1894, 100 pp., 13 illustrations, 4 maps — ----

**Bulletin No. 4. Catalogue of California Fossils, by J. G. Cooper. 1894, 73 pp., 67 illustrations. (Part I was published in the Seventh Annual Report of the State Mineralogist, 1887) — ----

**Bulletin No. 5. The Cyanide Process, 1894, by Dr. A. Scheidel. 140 pp., 46 illustrations — ----

**Bulletin No. 6. California Gold Mill Practices, 1895, by E. B. Preston. 85 pp., 46 illustrations — ----

**Bulletin No. 7. Mineral Production of California, by Counties, for the year 1894, by Charles G. Yale. Tabulated sheet — ----

**Bulletin No. 8. Mineral Production of California, by Counties, for the year 1895, by Charles G. Yale. Tabulated sheet — ----

**Bulletin No. 9. Mine Drainage, Pumps, etc., by Hans C. Behr. 1896, 210 pp., 206 illustrations — ----

**Bulletin No. 10. A Bibliography Relating to the Geology, Paleontology and Mineral Resources of California, by Anthony W. Vogdes. 1896, 121 pp. — ----

**Bulletin No. 11. Oil and Gas Yielding Formations of Los Angeles, Ventura and Santa Barbara Counties, by W. L. Watts. 1897, 94 pp., 6 maps, 31 illustrations — ----

**Bulletin No. 12. Mineral Production of California, by Counties, for 1896, by Charles G. Yale. Tabulated sheet — ----

**Bulletin No. 13. Mineral Production of California, by Counties, for 1897, by Charles G. Yale. Tabulated sheet — ----

**Bulletin No. 14. Mineral Production of California, by Counties, for 1898, by Charles G. Yale — ----

**Bulletin No. 15. Map of Oil City Fields, Fresno County, by John H. Means, 1899 — ----

**Bulletin No. 16. The genesis of Petroleum and Asphaltum in California, by A. S. Cooper. 1899, 39 pp., 29 illustrations — ----

BULLETINS—Continued

Asterisks (**) indicate the publication is out of print.

	Price (including postage and sales tax)
**Bulletin No. 17. Mineral Production of California, by Counties, for 1899, by Charles G. Yale. Tabulated sheet	----
**Bulletin No. 18. Mother Lode Region of California, by W. H. Storms, 1900, 154 pp., 49 illustrations	----
**Bulletin No. 19. Oil and Gas Yielding Formations of California, by W. L. Watts. 1900, 236 pp., 60 illustrations, 8 maps	----
**Bulletin No. 20. Synopsis of General Report of State Mining Bureau, by W. L. Watts. 1901, 21 pp. This bulletin contains a brief statement of the progress of the mineral industry in California for the four years ending December, 1899	----
**Bulletin No. 21. Mineral Production of California by Counties, by Charles G. Yale. 1900. Tabulated sheet	----
**Bulletin No. 22. Mineral Production of California for Fourteen Years, by Charles G. Yale. 1900. Tabulated sheet	----
Bulletin No. 23. The Copper Resources of California, by P. C. DuBois, F. M. Anderson, J. H. Tibbits and G. A. Tweedy. 1902, 282 pp., 69 illustrations, 9 maps — Price $0.75, sales tax $0.02	$0.77
**Bulletin No. 24. The Saline Deposits of California, by G. E. Bailey. 1902, 216 pp., 99 illustrations, 5 maps	----
**Bulletin No. 25. Mineral Production of California, by Counties, for 1901, by Charles G. Yale. Tabulated sheet	----
**Bulletin No. 26. Mineral Production of California for the Past Fifteen Years, by Charles G. Yale. 1902. Tabulated sheet	----
**Bulletin No. 27. The Quicksilver Resources of California, by William Forstner. 1903, 273 pp., 144 illustrations, 8 maps	----
**Bulletin No. 28. Mineral Production of California for 1902, by Charles G. Yale. Tabulated sheet	----
**Bulletin No. 29. Mineral Production of California for Sixteen Years, by Charles G. Yale. 1903. Tabulated sheet	----
**Bulletin No. 30. Bibliography Relating to the Geology, Palentology and Mineral Resources of California, by A. W. Vogdes. 1903, 290 pp.	----
**Bulletin No. 31. Chemical Analyses of California Petroleum, by H. N. Cooper. 1904. Tabulated sheet	------
**Bulletin No. 32. Production and Use of Petroleum in California by Paul W. Prutzman. 1904, 230 pp., 116 illustrations, 14 maps	----
**Bulletin No. 33. Mineral Production of California, by Counties, for 1903, by Charles G. Yale. Tabulated sheet	----
**Bulletin No. 34. Mineral Production of California for Seventeen Years, by Charles G. Yale. 1904. Tabulated sheet	----
**Bulletin No. 35. Mines and Minerals of California, by Charles G. Yale, 1904, 55 pp., 20 county maps. Relief maps of California	----
**Bulletin No. 36. Gold Dredging in California, by J. E. Doolittle. 1905. 120 pp., 60 illustrations, 3 maps	----
**Bulletin No. 37. Gems, Jewelers' Materials, and Ornamental Stones of California, by George F. Kunz. 1905, 168 pp., 54 illustrations	----
**Bulletin No. 38. Structural and Industrial Materials of California, by Wm. Forstner, T. C. Hopkins, C. Naramore and L. H. Eddy. 1906, 412 pp., 150 illustrations, 1 map	----
**Bulletin No. 39. Mineral Production of California, by Counties, for 1904, by Charles G. Yale. Tabulated sheet	----
**Bulletin No. 40. Mineral Production of California for Eighteen Years, by Charles G. Yale. 1905. Tabulated sheet	----
**Bulletin No. 41. Mines and Minerals of California for 1904, by Charles G. Yale. 1905, 54 pp., 20 county maps	----
**Bulletin No. 42. Mineral Production of California, by Counties, 1905, by Charles G. Yale. Tabulated sheet	----
**Bulletin No. 43. Mineral Production of California for Nineteen Years, by Charles G. Yale. Tabulated sheet	----
**Bulletin No. 44. California Mines and Minerals for 1905, by Charles G. Yale. 1907, 31 pp., 20 county maps	----

BULLETINS—Continued

Asterisks (**) indicate the publication is out of print.	Price (including postage and sales tax)
**Bulletin No. 45. Auriferous Black Sands of California, by J. A. Edman, 1907. 10 pp.	----
**Bulletin No. 46. General Index of Publications of the California State Mining Bureau, by Charles G. Yale. 1907, 54 pp.	----
**Bulletin No. 47. Mineral Production of California, by Counties, 1906, by Charles G. Yale. Tabulated sheet	----
**Bulletin No. 48. MineralProduction of California for Twenty Years, by Charles G. Yale. 1906	----
**Bulletin No. 49. Mines and Minerals of California for 1906, by Charles G. Yale. 34 pp.	----
Bulletin No. 50. The Copper Resources of California, 1908, by A. Hausmann, J. Kruttschnitt, Jr., W. E. Thorn and J. A. Edman, 366 pp., 74 illustrations. (Revised edition) ------Price $1.50, sales tax $0.04	$1.54
**Bulletin No. 51. Mineral Production of California, by Counties, 1907, by D. H. Walker. Tabulated sheet	----
**Bulletin No. 52. Mineral Production of California for Twenty-one Years, by D. H. Walker. 1907. Tabulated sheet	----
**Bulletin No. 53. Mineral Production of California for 1907, with County Maps, by D. H. Walker, 62 pp.	----
**Bulletin No. 54. Mineral Production of California, by Counties, by D. H. Walker. 1908. Tabulated sheet	----
**Bulletin No. 55. Mineral Production of California for Twenty-two Years, by D. H. Walker. 1908. Tabulated sheet	----
**Bulletin No. 56. Mineral Production for 1908, with County Maps and Mining Laws of California, by D. H. Walker, 78 pp.	----
**Bulletin No. 57. Gold Dredging in California by W. B. Winston and Chas. Janin. 1910, 312 pp., 239 illustrations, 10 maps	----
**Bulletin No. 58. Mineral Production of California, by Counties, by D. H. Walker. 1909. Tabulated sheet	----
**Bulletin No. 59. Mineral Production of California for Twenty-three Years, by D. H. Walker. 1900. Tabulated sheet	----
**Bulletin No. 60. Mineral Production for 1909, with County Maps and Mining Laws of California, by D. H. Walker. 94 pp.	----
**Bulletin No. 61. Mineral Production of California, by Counties, for 1910, by D. H. Walker. Tabulated sheet	----
**Bulletin No. 62. Mineral Production of California for Twenty-four Years, by D. H. Walker. 1910. Tabulated sheet	----
**Bulletin No. 63. Petroleum in Southern California, by P. W. Prutzman. 1912, 430 pp., 41 illustrations, 6 maps	----
**Bulletin No. 64. Mineral Production for 1911, by E. S. Boalich. 49 pp.	----
**Bulletin No. 65. Mineral Production for 1912, by E. S. Boalich. 64 pp.	----
**Bulletin No. 66. Mining Laws of the United States and California. 1914, 89 pp.	----
**Bulletin No. 67. Minerals of California, by Arthur S. Eakle. 1914, 226 pp.	----
**Bulletin No. 68. Mineral Production for 1913, with County Maps and Mining Laws, by E. S. Boalich. 160 pp.	----
**Bulletin No. 69. Petroleum Industry of California, with Folio of Maps (18 by 22), by R. P. McLaughlin and C. A. Waring. 1914, 519 pp., 13 illustrations, 83 figs. [18 plates in accompanying folio.]	----
**Bulletin No. 70. Mineral Production for 1914, with County Maps and Mining Laws. 184 pp.	----
**Bulletin No. 71. Mineral Production for 1915, with County Maps and Mining Laws, by Walter W. Bradley, 193 pp. 4 illustrations	----
**Bulletin No. 72. The Geoolgic Formations of California, by James Perrin Smith. 1916, 47 pp.	----
**Reconnaissance Geologic Map (of which Bulletin 72 is explanatory), in 23 colors. Scale: 1 inch = 12 miles. Mounted	----
**Bulletin No. 73. First Annual Report of the State Oil and Gas Supervisor of California for the fiscal year 1915-16, by R. P. McLaughlin. 278 pp., 26 illustrations	---

BULLETINS—Continued

Asterisks (**) indicate the publication is out of print.	Price (including postage and sales tax)
**Bulletin No. 74. Mineral Production of California in 1916, with County Maps, by Walter W. Bradley. 179 pp., 12 illustrations	----
**Bulletin No. 75. United States and California Mining Laws. 1917, 115 pp., paper	----
Bulletin No. 76. Manganese and Chromium in California, by Walter W. Bradley, Emile Huguenin, C. A. Logan, W. B. Tucker and C. A. Waring. 1918, 248 pp., 51 illustrations, 5 maps, paper Price $0.75, sales tax $0.02	$0.77
Bulletin No. 77. Catalogue of Publications of California State Mining Bureau, 1880-1917, by E. S. Boalich. 44 pp., paper	Free
**Bulletin No. 78. Quicksilver Resources of California, with a Section on Metallurgy and Ore-Dressing, by Walter W. Bradley. 1919, 389 pp., 77 photographs and 42 plates (colored and line cuts), cloth	----
Bulletin No. 79. Magnesite in California, by Walter W. Bradley. 1925, 147 pp., 62 photographs, 11 line cuts and maps, cloth Price $1.25, sales tax $0.03	1.28
†Bulletin No. 80. Tungsten. Molybdenum and Vanadium in California. (Not issued—See Apr. 1941 Chap. Report XXXVII.)	
†Bulletin No. 81. Foothill Copper Belt of California. (Not issued.)	
**Bulletin No. 82. Second Annual Report of the State Oil and Gas Supervisor, for the Fiscal Year 1916-1917, by R. P. McLaughlin. 1918, 412 pp., 31 illustrations, cloth	----
**Bulletin No. 83. California Mineral Production for 1917, with County Maps, by Walter W. Bradley. 179 pp., paper	----
**Bulletin No. 84. Third Annual Report of the State Oil and Gas Supervisor, for the Fiscal Year 1917-1918, by R. P. McLaughlin. 1918, 617 pp., 28 illustrations, cloth	----
**Bulletin No. 85. Platinum and Allied Metals in California, by C. A. Logan, 1919. 10 photographs, 4 plates, 120 pp., paper	----
**Bulletin No. 86. California Mineral Production for 1918, with County Maps, by Walter W. Bradley. 1919, 212 pp., paper	----
**Bulletin No. 87. Commercial Minerals of California, with notes on their uses, distribution, properties, ores, field tests and preparation for market, by W. O. Castello. 1920, 124 pp., paper	----
**Bulletin No. 88. California Mineral Production for 1919, with County Maps, by Walter W. Bradley. 1920, 204 pp., paper	----
**Bulletin No. 89. Petroleum Resources of California, with Special Reference to Unproved Areas, by Lawrence Vander Leck. 1921, 12 figures, 6 photographs, 6 maps in pocket, 186 pp., cloth	----
**Bulletin No. 90. California Mineral Production for 1920, with County Maps, by Walter W. Bradley. 1921, 218 pp., paper	----
**Bulletin No. 91. Minerals of California, by Arthur S. Eakle. 1923, 328 pp., cloth	----
**Bulletin No. 92. Gold Placers of California, by Charles S. Haley. 1923, 167 pp., 36 photographs and 7 plates (colored and line cuts, also geological map), cloth	----
**Bulletin No. 93. California Mineral Production for 1922, by Walter W. Bradley. 1923, 188 pp., paper	----
**Bulletin No. 94. California Mineral Production for 1923, by Walter W. Bradley. 1924, 162 pp., paper	----
**Bulletin No. 95. Geology and Ore Deposits of the Randsburg Qaudrangle, by Carlton D. Hulin. 1925, 152 pp., 49 photographs, 13 line cuts, 1 colored geologic map, cloth	----
**Bulletin No. 96. California Mineral Production for 1924, by Walter W. Bradley. 1925, 173 pp., paper	----
**Bulletin No. 97. California Mineral Production for 1925, by Walter W. Bradley. 1926, 172 pp., paper	----

† Not issued.

BULLETINS—Continued

Asterisks (**) indicate the publication is out of print. — Price (including postage and sales tax)

Bulletin No. 98. American Mining Law, by A. H. Ricketts, 1931, 811 pp., flexible leather____Price $2.50, sales tax $0.06 $2.56

Bulletin No. 99. Clay Resources and Ceramic Industry of California, by Waldemar Fenn Deitrich. 1928, 383 pp., 70 photographs, 12 line cuts including maps, cloth____Price $2.00, sales tax $0.05 2.05

**Bulletin No. 100. California Mineral Production for 1926, by Walter W. Bradley, 1927, 174 pp., paper____ ----

**Bulletin No. 101. California Mineral Production for 1927, by Henry H. Symons. 1928, 311 pp., paper____ ----

**Bulletin No. 102. California Mineral Production for 1928, by Henry H. Symons. 1929, 210 pp., paper____ ----

Bulletin No. 103. California Mineral Production for 1929, by Henry H. Symons. 1930, 231 pp., paper____ ----

Bulletin No. 104. Bibliography of the Geology and Mineral Resources of California, to the end of 1930, by Solon Shedd____ Price $2.50, sales tax $0.06 2.56

Bulletin No. 105. Mineral Production in California for 1930 and Directory of Producers, by Henry H. Symons. 1931

Bulletin No. 106. Superseded. (See Bulletin No. 120.)

Bulletin No. 107. Mineral Production in California for 1931 and Directory of Producers, by Henry H. Symons. 1932

Bulletin No. 108. Mother Lode Gold Belt of California, by Clarence A. Logan, 1934, 240 pp., with geologic and claim maps, cloth____ Price $2.25, sales tax $0.06 2.31

Bulletin No. 109. California Mineral Production and Directory of Mineral Producers for 1932, by Henry H. Symons, 200 pp., paper____ ----

Bulletin No. 110. California Mineral Production and Director of Mineral Producers for 1933, by Henry H. Symons, 214 pp., paper____ ----

Bulletin No. 111. California Mineral Production and Directory of Mineral Producers for 1934, by Henry H. Symons, 334 pp., paper____ ----

Bulletin No. 112. California Mineral Production and Directory of Mineral Producers for 1935, by Henry H. Symons, 205 pp., paper____ ----

Bulletin No. 113. Minerals of California, by Adolf Pabst, 1938____ ---- Price $1.75, sales tax $0.04 1.79

Bulletin No. 114. California Mineral Production and Directory of Mineral Producers for 1936, by Henry H. Symons, 119 pp., paper____ ----

Bulletin No. 115. Bibliography of Geology and Mineral Resources of California, 1931 to 1936, by Solon Shedd, Supplementing Bulletin No. 104 ____Price $1.25, sales tax $0.03 1.28

Bulletin No. 116. California Mineral Production and Directory of Mineral Producers for 1937, by Henry H. Symons. 1938

Bulletin No. 117. California Mineral Production and Director of Mineral Producers for 1938, by Henry H. Symons. 1939

Bulletin No. 118

Geologic Formations and Economic Development of the Oil and Gas Fields of California, by O. P. Jenkins and others

Part One—Development of the Industry, 1940

Part Two—Geology of California and the Occurrence of Oil and Gas, 1941

Part Three—Descriptions of Individual Oil and Gas Fields, 1943

Part Four—Glossaries, Bibliography, Map and Index, 1943

Four parts, paper covers; the set $4.00, sales tax $0.10 4.10

Bulletin No. 118. Cloth bound____Price $6.00, sales tax $0.15 6.15

**Bulletin No. 119. Mineral Production of California for 1939, and Directory of Producers, by Henry H. Symons. 1940____ ----

**Bulletin No. 120. Manner of Locating and Holding Mineral Claims in California (with forms), by A. H. Ricketts (revised 1941)____ ----

Bulletin No. 121. Mineral Production of California for 1940, and Directory of Producers, by Henry H. Symons. 1941____ Free

Bulletin No. 122. Mineral Production of California for 1941; Directory of Producers, and Tables of Total Recorded Production by Counties, by Henry H. Symons, 377 pp., paper____ Free

BULLETINS—Continued

Asterisks (**) indicate the publication is out of print.	Price (including postage and sales tax)
Bulletin No. 123. American Mining Law, by A. H. Ricketts, 1943, 1008 pp., cloth----Price $5.00, sales tax $0.13	$5.13
Bulletin No. 124. Commercial Minerals of California, by George L. Gary. A loose-leaf mimeographed bulletin arranged so that it may be revised and supplemented. 1942----Price $1.00, sales tax $0.03	1.03
With binder ----Price $1.20, sales tax $0.04	1.24
Revised papers mailed upon receipt of postage	
Bulletin No. 125. Manganese in California (in press).	
Bulletin No. 126. Mineral Production of California for 1942, and Directory of Producers, by Henry H. Symons, 1943----Price $0.80, sales tax $0.02	.82
Bulletin No. 127. Manner of Locating and Holding Mineral Claims in California (with forms), by A. H. Ricketts (revised 1944)----Price $0.25, sales tax $0.01	.26

PRELIMINARY REPORTS

**Preliminary Report No. 1. Notes on Damage by Water in California Oil Fields, December, 1913. By R. P. McLaughlin, 4 pp.----	----
**Preliminary Report No. 2. Notes on Damage by Water in California Oil Fields, March, 1914. By R. P. McLaughlin, 4 pp.----	----
Preliminary Report No. 3. Manganese and Chromium, 1917. By E. S. Boalich. 32 pp.----	Free
**Preliminary Report No. 4. Tungsten, Molybdenum and Vanadium. By E. S. Boalich and W. O. Castello, 1918. 34 pp. Paper----	----
**Preliminary Report No. 5. Antimony, Graphite, Nickel, Potash, Strontium and Tin. By E. S. Boalich and W. O. Castello, 1918. 44 pp. Paper	----
Preliminary Report No. 6. A Review of Mining in California During 1919. By Fletcher Hamilton, 1920. 43 pp. Paper----	Free
**Preliminary Report No. 7. The Clay Industry in California. By E. S. Boalich, W. O. Castello, E. Huguenin, C. A. Logan, and W. B. Tucker, 1920. 102 pp. 24 illustrations. Paper----	----
**Preliminary Report No. 8. A Review of Mining in California During 1921, with Notes on the Outlook for 1922. By Fletcher Hamilton, 1922. 68 pp. Paper----	----

MINERAL ABSTRACTS

Antimony, 26 pp.----Price $0.25, sales tax $0.01	.26
Iron, 52 pp.----Price $0.35, sales tax $0.01	.36
Pumice and Volcanic Ash, 50 pp.----Price $0.35, sales tax $0.01	.36
Sulphur, 23 pp.----Price $0.25, sales tax $0.01	.26
Tungsten, 33 pp.----Price $0.25, sales tax $0.01	.26

MISCELLANEOUS PUBLICATIONS

**First Annual Catalogue of the State Museum of California, being the collection made by the State Mining Bureau during the year ending April 16, 1881. 350 pp.----	----
**Catalogue of books, maps, lithographs, photographs, etc., in the library of the State Mining Bureau at San Francisco, May 15, 1884. 19 pp.----	----
**Catalogue of the State Museum of California, Volume II, being the collection made by the State Mining Bureau from April 16, 1881, to May 5, 1884. 220 pp.----	----
**Catalogue of the State Museum of California, Volume III, being the collection made by the State Mining Bureau from May 15, 1884, to March 31, 1887. 195 pp.----	----
**Catalogue of the State Museum of California, Volume IV, being the collection made by the State Mining Bureau from March 30, 1887, to August 20, 1890. 261 pp.----	----

MISCELLANEOUS PUBLICATIONS—Continued

Asterisks (**) indicate the publication is out of print.

	Price (including postage and sales tax)
Lakes of California ---- Price $0.25, sales tax $0.01	$0.26
In lots of 50 or more, C. O. D. ----	.10
Drift Mining in California (Reprint) ---- Price $0.25, sales tax $0.01	.26
**Catalogue of the Library of the California State Mining Bureau, September 1, 1892. 149 pp. ----	----
**Catalogue of West North American and Many Foreign Shells with Their Geographical Ranges, by J. G. Cooper. Printed for the State Mining Bureau, April, 1894 ----	----
**Report of the Board of Trustees for the four years ending September, 1900. 15 pp. Paper ----	----
Reconnaissance of the Colorado Desert Mining District. By Stephen Bowers, 1901. 19 pp. 2 illustrations. Paper ----	Free
Commercial Mineral Notes. A monthly mimeographed sheet, beginning April, 1923 ---- (by mail 25¢ annually)	Free

Write for latest revised price list.

MAPS

Register of Mines with Maps

**Register of Mines, with Map, Amador County ----	----
Register of Mines, with Map, Butte County ---- Price $0.15, sales tax $0.01	.16
**Register of Mines, with Map, Calaveras County ----	----
**Register of Mines, with Map, El Dorado County ----	----
**Register of Mines, with Map, Inyo County ----	----
**Register of Mines, with Map, Kern County ----	----
**Register of Mines, with Map, Lake County ----	----
**Register of Mines, with Map, Mariposa County ----	----
Register of Mines, with Map, Nevada County ----	Free
**Register of Mines, with Map, Placer County ----	----
**Register of Mines, with Map, Plumas County ----	----
**Register of Mines, with Map, San Bernardino County ----	----
Register of Mines, with Map, San Diego County ----	Free
Register of Mines, with Map, Santa Barbara County (1906) ---- Price $0.15, sales tax $0.01	.16
**Register of Mines, with Map, Shasta County ----	----
**Register of Mines, with Map, Sierra County ----	----
**Register of Mines, with Map, Siskiyou County ----	----
**Register of Mines, with Map, Trinity County ----	----
**Register of Mines, with Map, Tuolumne County ----	----
Register of Mines, with Map, Yuba County (1905) ---- Price $0.15, sales tax $0.01	.16
**Register of Oil Wells, with Map, Los Angeles City (1906) ----	----

Other Maps

**Map of California, Showing Mineral Deposits (50x60 in.) ----	----
**Map of Forest Reserves in California ----	----
**Mineral and Relief Map of California ----	----
**Map of El Dorado County, Showing Boundaries, National Forests ----	----
**Map of Madera County, Showing Boundaries, National Forests ----	----
**Map of Placer County, Showing Boundaries, National Forests ----	----
**Map of Shasta County, Showing Boundaries, National Forests ----	----
**Map of Sierra County, Showing Boundaries, National Forests ----	----
**Map of Siskiyou County, Showing Boundaries, National Forests ----	----
**Map of Tuolumne County, Showing Boundaries, National Forests ----	----
**Map of Mother Lode Region ----	----
**Map of Desert Region of Southern California ----	----
Map of Minaret District, Madera County ----	.10
**Map of Copper Deposits in California ----	----

Other Maps—Continued

Asterisks (**) indicate the publication is out of print.

	Price (including postage and sales tax)
**Map of Calaveras County	----
**Map of Plumas County	----
**Map of Trinity County	----
**Map of Tuolumne County	----
**Geographical Map of Inyo County. Scale 1 inch equals 4 miles	----
**Map of California accompanying Bulletin No. 89, showing generalized classification of land with regard to oil possibilities. Map only, without Bulletin	----
**Geologic Map of California, 1916. Scale 1 inch equals 12 miles. Shows railroads, highways, post offices and other towns. Geological details lithographed in 23 colors. Mounted	----
**Unmounted	----
Geologic Map of California, 1938. Scale 8 miles per inch. Lithographed in 80 distinguishing colors and patterns showing geologic units. In 6 sections, each 32 in. x 42 in. Set of 6 sheets, unmounted. Sheets not sold separately — Price $4.00, sales tax $0.10	$4.10
Economic Series:	
No. 1. Quicksilver	
No. 2. Oil and Gas	
No. 3. Chromite	
No. 4. Tungsten	
No. 5. Manganese	
(See under separate listings below for prices)	
**Topographic Map of Sierra Nevada Gold Belt, showing distribution of auriferous gravels, accompanying Bulletin No. 92. In 4 colors	----
Geologic Map of Northern Sierra Nevada, showing Tertiary River Channels and Mother Lode Belt accompanying July-October Chapter of Report XXVIII of the State Mineralogist. (Sold singly) — Price $0.25, sales tax $0.01	.26
Map of Northern California, showing rivers and creeks which produced placer gold in 1932 — Price $0.15, sales tax $0.01	.16
Mother Lode Geologic and claim maps in 5 county sections: El Dorado, Amador, Calaveras, Tuolumne and Mariposa — Price $0.15, sales tax $0.01	.16
Map of Mariposa County, showing principal gold mines — Price $0.15, sales tax $0.01	.16
Geologic Map of Elizabeth Lake Quadrangle, Los Angeles and Kern Counties (accompanying October Chapter of Report XXX), sold separately — Price	.10
Map of Western Portion of Siskiyou County Showing Location of Principal Gold Mines (accompanying July Chapter of Report XXXI), sold separately — Price $0.15, sales tax $0.01	.16
Geologic Map of Redding and Weaverville Quadrangles Showing Location of Gold Mines — Price $0.15, sales tax $0.01	.16
Manganese Deposits, accompanying Bulletin 125, Map separately — Price $0.60, sales tax $0.02	.62
Map of Ancient Channel System, Calaveras County Map of Ancient Channels Between San Andreas and Mokelumne Hill Set of 2 — Price $0.25, sales tax $0.01	.26
Minaret	.10
Perris Block Geologic	.10
Plumas County Geologic — Price $0.15, sales tax $0.01	.16
Shasta County — Price $0.15, sales tax $0.01	.16
El Dorado County — Price $0.15, sales tax $0.01	.16
Trinity County, Showing Locations of Principal Mineral Deposits (accompanying Jan. Chapt. of Report XXXVII) — Price $0.15, sales tax $0.01	.16
Quicksilver deposits, sold in conjunction with October 1939, Chapter of Report XXXV, Map separately — Price $0.50, sales tax $0.01	.51
Nevada County (accompanying July Chapter of Report XXXVII) — Price $0.15, sales tax $0.01	.16

Other Maps—Continued

Asterisks (**) indicate the publication is out of print.	Price (including postage and sales tax)
Grass Valley and Nevada City District claim map ---------- Price	$0.10
Oil and Gas Fields Map, accompanying Bulletin 118, Map separately ---- Price $1.00, sales tax $0.03	1.03
Chromite deposits ---------- Price $0.60, sales tax $0.02	.62
Tungsten deposits, sold in conjunction with July-October 1942 Chapter of Report XXXVIII, Map separately ---------- Price $0.60, sales tax $0.02	.62

OIL AND GAS FIELD MAPS

The following maps are on sale at the State Division of Oil and Gas, Ferry Building, San Francisco, and the various branch offices. The maps are revised as development work advances and ownerships change. Price includes postage.

No.		*Price*
1	Sargent, Santa Clara County	$0.75
2	Santa Maria, including Cat Canyon—Los Alamos, Santa Barbara County	1.25
3	Santa Maria, including Casmalia and Lompoc, Santa Barbara County	1.25
4	Brea Olinda and East Coyote, Los Angeles, Orange Counties	1.25
6	Salt Lake—Beverly Hills, Los Angeles County	1.25
7	Sunset, including San Emidio, Kern County	1.25
8	South Midway, including Buena Vista Hills, Kern County	1.25
9	North Midway and McKittrick, Kern and San Luis Obispo Counties	1.25
10	South Belridge and McKittrick-Temblor oil fields, Kern County	1.25
11	Lost Hills and North Belridge, including Antelope Hills, Kern County	1.25
12	Devils Den, Kern County	1.00
13	Kern River and Kern Front fields, including portion of Poso Creek field, Kern County	1.00
14	Coalinga and East Coalinga Extension, Fresno County	1.50
15	Elk Hills, Kern County	1.25
16	Ventura-Ojai, Ventura County	1.25
17	Santa Paula-Ojai, including South Mountain, Ventura County	1.25
18	Sespe-Piru-Simi, including Bardsdale, Ventura County	1.50
18a	Newhall, Aliso Canyon, Newhall-Potrero, Del Valle and Oak Canyon, Los Angeles County	1.25
19	Arroyo Grande, San Luis Obispo County	1.00
20	Long Beach, Los Angeles County	1.75
21B	District 5, boundaries of areas including oil fields, Fresno, Kings and Kern Counties	1.00
21C	District 4, boundaries of areas including oil fields, Kern, Kings and Tulare Counties	1.25
22	District 3, boundaries of areas including oil fields, Santa Barbara County	.75
23	District 2, boundaries of areas including oil fields, Ventura County	1.00
24	District 1, boundaries of areas including oil fields, Los Angeles and Orange Counties	1.00
26	Huntington Beach, Orange County	1.50
27	Santa Fe Springs, Los Angeles County	1.25
28	Torrance, Los Angeles County	1.25
28a	Townlot area, Torrance field, Los Angeles County	.75
29	Dominguez, Los Angeles County	1.00
30	Rosecrans, Los Angeles County	1.25
31	Inglewood, Los Angeles County	1.25
32	Seal Beach, Los Angeles and Orange Counties	1.25
33	Rincon, Ventura County	1.50
34	Mt. Poso and Poso Creek, Kern County	1.00
35	Round Mountain, Kern County	1.00
36	Kettleman North Dome and Middle Dome, Fresno and Kings Counties	1.50
37	Montebello, Los Angeles County	1.00
38	Whittier, Los Angeles County	1.25

OIL AND GAS FIELD MAPS—Continued

No.	Price
39—West Coyote Oil Field, Los Angeles and Orange Counties	1.25
40—Elwood, Goleta (abandoned), La Goleta (gas), Santa Barbara County	1.25
41—Potrero, Los Angeles County	1.00
42—Playa del Rey, Los Angeles County	1.50
43—Capitan, Santa Barbara County	1.00
44—Mesa, Santa Barbara County	1.50
46—Richfield, Orange County	1.25
48—Mountain View and Edison, Kern County	1.25
49—Fruitvale, Kern County	1.00
50—Wilmington, Los Angeles County	1.25
51—Santa Maria Valley, Santa Barbara County	1.00
52—El Segundo and Lawndale, Los Angeles County	$1.50
53—Rio Bravo and Greeley, Kern County	1.00
54—Wasco oil field, Buttonwillow and Semitropic (gas), Kern County	1.25
55—Canal, Canfield Ranch, Coles Levee, Strand, Ten Section, Kern County	1.25
56—Paloma, Kern County	1.25
57—Rio Vista (gas), Sacramento, Solano, and Contra Costa Counties	1.00
58—Trico Gas, Kern, Kings and Tulare Counties	1.00
59—Raisin City, Helm and Riverdale, including Wheatville area, Fresno County	1.25

o

33963 4-44 2M

STATE OF CALIFORNIA
DEPARTMENT OF NATURAL RESOURCES
WARREN T. HANNUM, Director

DIVISION OF MINES
FERRY BUILDING, SAN FRANCISCO

WALTER W. BRADLEY State Mineralogist

Vol. 40 April 1944 No. 2

CALIFORNIA JOURNAL
OF
MINES AND GEOLOGY

QUARTERLY CHAPTER
OF
STATE MINERALOGIST'S REPORT XL

36585

DIVISION OF MINES

EXECUTIVE AND TECHNICAL STAFF

WALTER W. BRADLEY

State Mineralogist

OLAF P. JENKINS, Chief Geologist ---------- San Francisco

C. A. LOGAN, District Mining Engineer ---------- Sacramento

W. BURLING TUCKER, District Mining Engineer ---------- Los Angeles

CHAS. V. AVERILL, District Mining Engineer ---------- San Francisco

J. C. O'BRIEN, District Mining Engineer ---------- Redding

REID J. SAMPSON, Assistant District Mining Engineer ---------- Los Angeles

GEORGE L. GARY, Mineral Technologist ---------- San Francisco

JOHN F. BONGARD, Ore-Buyers' Inspector* ---------- San Francisco

HENRY H. SYMONS, Statistician and Curator ---------- San Francisco

JAMES M. LITTLE, Junior Mining Engineer (Librarian) ---------- San Francisco

ELISABETH L. EGENHOFF, Editor, Geologic Branch ---------- San Francisco

FENELON F. DAVIS, Geological Draftsman ---------- San Francisco

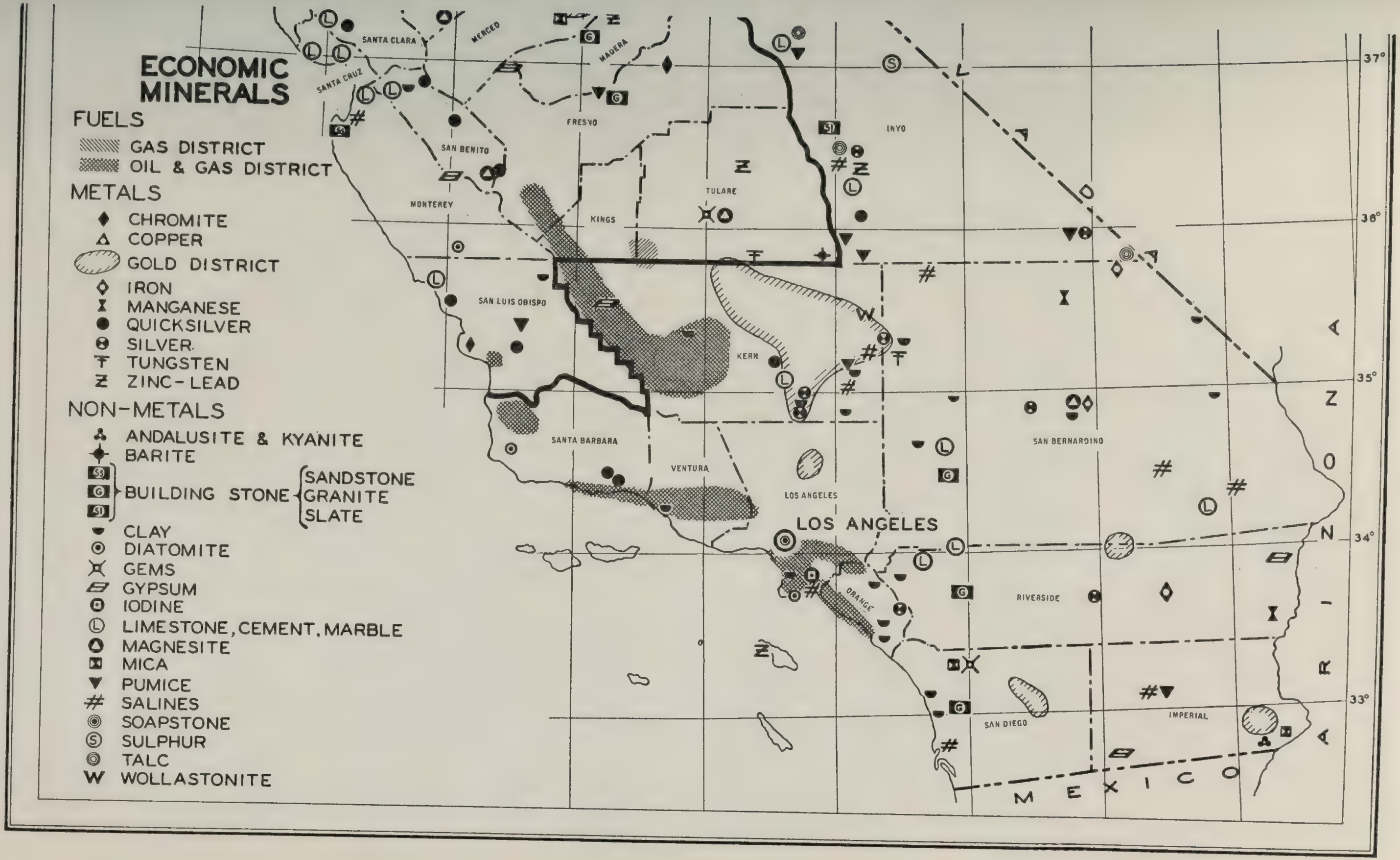
MARY HELM, Geological Draftsman ---------- San Francisco

* On leave for military service.

CONTENTS

PLATES


INDEX MAP
OF
ECONOMIC MINERALS
IN
CALIFORNIA
AND THE
DISTRICTS OF THE DIVISION OF MINES
SCALE
0
50
100
200 MI.
CALIFORNIA STATE DIVISION OF MINES
1943
DISTRICT OFFICES OF THE DIVISION OF MINES
San Francisco (main office)
Los Angeles
Sacramento
Redding
BOUNDARIES OF THE DISTRICTS
OREGON
NEVADA
REDDING
SACRAMENTO
SAN FRANCISCO
DEL NORTE
SISKIYOU
MODOC
HUMBOLDT
TRINITY
SHASTA
LASSEN
TEHAMA
PLUMAS
MENDOCINO
GLENN
BUTTE
SIERRA
YUBA
NEVADA
PLACER
LAKE
COLUSA
SUTTER
EL DORADO
YOLO
ALPINE
SONOMA
NAPA
AMADOR
SOLANO
SACRAMENTO
CALAVERAS
MARIN
SAN JOAQUIN
MONO
TUOLUMNE
CONTRA COSTA
ALAMEDA
SAN MATEO
STANISLAUS
MARIPOSA
124°
123°
122°
121°
120°
119°
118°
117°
116°
115°
114°
42°
41°
40°
39°
38°


ECONOMIC MINERALS
FUELS
GAS DISTRICT
OIL & GAS DISTRICT
METALS
CHROMITE
COPPER
GOLD DISTRICT
IRON
MANGANESE
QUICKSILVER
SILVER
TUNGSTEN
ZINC-LEAD
NON-METALS
ANDALUSITE & KYANITE
BARITE
BUILDING STONE
SANDSTONE
GRANITE
SLATE
CLAY
DIATOMITE
GEMS
GYPSUM
IODINE
LIMESTONE, CEMENT, MARBLE
MAGNESITE
MICA
PUMICE
SALINES
SOAPSTONE
SULPHUR
TALC
WOLLASTONITE
SANTA CLARA
SANTA CRUZ
MERCED
MADERA
FRESNO
SAN BENITO
MONTEREY
KINGS
TULARE
INYO
SAN LUIS OBISPO
KERN
SANTA BARBARA
VENTURA
LOS ANGELES
SAN BERNARDINO
LOS ANGELES
ORANGE
RIVERSIDE
SAN DIEGO
IMPERIAL
37°
36°
35°
34°
33°
N
E
V
A
D
A
A
R
I
Z
O
N
A
M
E
X
I
C
O

ADMINISTRATION

ADMINISTRATIVE REPORT

By Walter W. Bradley, State Mineralogist

Personnel

James M. Little, appointed in February to the position of junior mining engineer, has been assigned the duties of librarian in the San Francisco headquarters of the Division. He graduated at Columbia University in 1907 with the degree of Mining Engineer, and has been engaged in mining and geological work in Arizona, Mexico, South America, and California.

Charles V. Averill, district mining engineer, has been transferred from the Sacramento district office to the San Francisco headquarters, vice Clyde McK. Laizure, deceased.

Clarence A. Logan, district mining engineer, has been transferred back to the Sacramento district office, which he occupied for several years before being assigned to a state-wide survey of the minerals on state lands under the State Lands Commission.

New Publications

Since last noted, the following publication of the Division of Mines has been received from the State Printer, and is now available at the offices of the Division:

CALIFORNIA JOURNAL OF MINES AND GEOLOGY, April 1943, being Chapter 2 of State Mineralogist's Report XXXIX. This chapter contains: *Administrative Report; Manganese Discovery in San Mateo County; Current Mining Activity in Southern California; Current Notes on Activity in the Strategic Minerals, Sacramento Field District; Clerbus Mae Tungsten Prospect, Trinity County; Current Notes, Geologic Branch; Mylonites in the Eastern San Gabriel Mountains; Geology of the Sierra Nevada Northeast of Visalia, Tulare County; Tungsten Deposits Northeast of Visalia; Geology of the San Benito Quadrangle* (with geologic map); *Current Notes on Exhibits,* and *Statistics of Mineral Production;* Laboratory notes, and papers on lithium and quartz.

GEOLOGIC BRANCH

CURRENT NOTES

By Olaf P. Jenkins*

In This Issue

The Geology of the Jamesburg Quadrangle, Monterey County, California, by William Morris Fiedler which appears in this issue of the JOURNAL is accompanied by a geologic map lithographed in colors and printed on the topographic base map of the United States Geological Survey. This is the most useful type of geologic map because the rock formations are printed on top of the surface contours. It represents the second of a series of such maps (the first being the San Benito quadrangle of April 1943) which the Division of Mines expects to publish in the future.

In order to lay the foundation for further geologic mapping it is necessary to have adequate topographic quadrangles. One of the important projects in post-war planning is a state-wide program for making topographic maps. The following report *Status of Topographic and Geologic Mapping in California* has been prepared to serve as a graphic inventory of what has been done in the past. The two maps which accompany this report clearly show that the principal mineral areas of the State are the very areas which have the least number of adequate maps. To provide the mineral industry with adequate maps, both topographic and geologic, would be a material help as well as a stimulus to further discovery and economic development of California's mineral resources.

In Preparation

The July issue of the CALIFORNIA JOURNAL OF MINES AND GEOLOGY will contain an interesting and enlightening paper, *Mines and Quarries of the Indians of California,* by Robert F. Heizer and Adan E. Treganza, who are anthropologists particularly qualified to present this study, which serves as a background to the history of the mineral industry of California.

Also in the July issue will be a geologic report on *Iron Ore Deposits in the Eastern Part of the Eagle Mountains, Riverside County, California,* by Jarvis B. Hadley. The report and the several maps which accompany it represent a contribution from the United States Geological Survey who made the investigation in cooperation with the United States Bureau of Mines in 1942.

* Chief Geologist, Division of Mines.

STATUS OF TOPOGRAPHIC AND GEOLOGIC MAPPING IN CALIFORNIA

By Olaf P. Jenkins *

OUTLINE OF REPORT

INTRODUCTION

The object of this report is to take stock of the topographic and geologic maps of California (as of July 1944); to show the relationship of these maps to the mineral provinces of the State; and to provide a basis for a plan of postwar mapping which would aid the mineral industry to expand and, in expanding, give employment to returned service men. Such mapping stimulates various enterprises; assists in the development of all manner of industries; and aids in the discovery of new mineral deposits.

Topographic maps of high quality, showing in detail every irregularity in surface form, express many geologic features which in turn help to show the position and structure of mineral deposits.

It is necessary, however, to formulate a program of mapping that is all-embracing and well coordinated, for topographic and geologic maps of high quality are needed in manifold industries and activities besides the mineral industry. Among these are: military operations; forestry; lumbering; geological and mineral examinations; mining development; oil and gas industry; agriculture; soil surveys; water resources and ground-water investigations; erosion control; development of parks, recreation, and natural resources of fish and game; land reclamation; road and bridge location; engineering construction; location of pipelines; tax assessments; insurance; education; archaeology, zoology, botany, seismology; studies of landslides and all surface forms.

Usefulness of maps depends also on their being completed as soon as possible and made generally available. Cost and efficiency are affected favorably by a broad program of work. The cost of mapping an isolated quadrangle would be extremely expensive as compared with the cost of mapping the same quadrangle in a group. The flying necessary to obtain aerial photographs would cost nearly as much for one quadrangle as for a group of quadrangles. An active, extensive, and speedy plan should be initiated at an early date, if full value is to be gained from the project.

PRESENT STATUS OF TOPOGRAPHIC MAPPING

The accompanying index map shows graphically and in colors the status of topographic mapping in California by quadrangles of the

* Chief Geologist, Geologic Branch of the California State Division of Mines.
Manuscript submitted for publication August 21, 1944.

United States Geological Survey; also of the War Department and Forest Service. In this report, the scale of 1:62,500 (15-minute sheet) is considered both adequate and standard for an "all-purpose" topographic quadrangle. Larger scales (particularly 1:31,680, the 7½-minute sheet) are considered necessary for more rigid requirements; but smaller scales than 1:62,500 (such as 1:125,000) have become nearly obsolete for use in geological mapping or in other enterprises, scientific, engineering, or commercial.

The average area of the 15-minute quadrangle in California is about 238 square miles. It would take more than 700 such quadrangles to cover the State. About half of the State has been mapped on this and larger scales, though a third of this area is in need of revision. Most of the adequate maps have been made of the coastal region, but very few cover the more highly mineralized mountainous regions.

Scale of maps

State map	1:500,000	approximately 1″ = 8 mi.
1° quadrangle	1:250,000	approximately 1″ = 4 mi.
30′ quadrangle	1:125,000	approximately 1″ = 2 mi.
15′ quadrangle	1:62,500	approximately 1″ = 1 mi.
7½′ quadrangle	1:31,680	approximately 1″ = ½ mi.
6′ quadrangle	1:24,000	approximately 1″ = 2000 ft.
Aerial photographs	1:20,000	(A.A.A. and Forest Service)
Multiplex	1:10,000	(original scale of drawing before publication)

The Topographic Branch of the Geological Survey, Department of the Interior, is recognized as being the best qualified agency in the United States for making topographic maps of highest quality. Through many years of continuous and careful work the Survey has steadily improved the quality and accuracy of its maps.

The latest development in topographic mapping is the Multiplex method of accurately drawing contours and culture from a stereoscopic model projected from aerial photographs made especially for that work. The original drawing is usually made on the scale of 1:10,000, and is extraordinarily precise, showing in detail every feature which can be seen from the air. Though the final published work may be greatly reduced in scale, a photostat copy of the original drawing can be secured and used for special examination work, prior to the publication of the quadrangle. Revision of topographic maps can be made from time to time with very little work. The locations of mines, quarries, and all surface development operations are accurately and easily put on these maps. The final cost of these maps is no greater than that of the older planetable work. Mountainous and inaccessible areas are no problem to the Multiplex.

As might be expected, the earlier work of the Survey did not have the high standard of accuracy which is maintained today. Those maps surveyed prior to 1900 are now considered by the Geological Survey as inadequate for modern use. Some of the earlier maps were published on the scale of 1:250,000; these are only reconnaissance sheets. Up to a few years ago the scale of 1:125,000 was considered sufficiently accurate for use in mountainous regions. The scale of 1:62,500 is now considered to be most generally satisfactory for various purposes. The scale of 1:31,680, however, is rapidly becoming necessary especially in regions of low relief. Eventually this larger scale may be the general standard

map scale for California, as is the case in many of the middle-western and eastern States.

Though all topographic work is now done with the use of aerial photographs, the method of their employment varies, and as a result the accuracy of the maps is not uniform. The use of the most modern equipment developed by the Survey (the Multiplex) has not yet been applied to mapping in California. Its employment would undoubtedly initiate a distinct improvement in maps of this State as it has done elsewhere.

In California, the Forest Service (United States Department of Agriculture) has mapped the topography of large areas of National Forests on the scale of $\frac{1}{2}'' = 1$ mile. These maps are now considered to be reconnaissance, and inadequate for the rigid requirements of modern investigations. More recently the Forest Service has prepared certain planimetric maps (one area in the northern Sierra Nevada; another about Point Arena) made from aerial photographs. After contours have been drawn upon these maps they will represent a topographic map of first quality. The Forest Service is preparing these to conform with the regular standard quadrangle. As a contribution to the war effort the topography of a number of quadrangles (one district in northwestern California and another in the southern Coast Ranges) have already been mapped by the Forest Service, using a device known as the "KEK Plotter," which has proved to be satisfactory in drawing contours from aerial photographs. All the work of the Forest Service is made available to the Geological Survey for the final publication of topographic quadrangles by the Survey.

As an emergency measure, the War Department has prepared and published (though not made generally available) in a comparatively short time a large number of topographic quadrangles, for the most part located in the coastal region. The objective has been military and therefore the results have not been the same as those obtained by the Geological Survey. For example, the maps do not contain the land net. The work has received the support of all governmental agencies including the Geological Survey and Forest Service. The maps are drawn, for the most part, on the scale of 1:62,500. Their accuracy and quality are not uniform, although they have all been made from aerial photographs. The results of the work are available to the Geological Survey, and any part may be incorporated in the final maps of the Survey.

Private agencies such as the Fairchild Aerial Surveys, Inc. have been employed by the Federal departments in the making of topographic maps, especially in the mechanical drawing of contours from aerial photographs. Maps by the Fairchild Corporation have proved to be satisfactory.

Aerial photographs, covering a large portion of the State, have been made by the Agriculture Adjustment Administration and Forest Service, both of the United States Department of Agriculture. Many of the important mineral lands are not covered by aerial photographs of any sort.

The Coast and Geodetic Survey (United States Department of Commerce) has published generalized topographic maps on the scale of 1:500,000 covering the entire area of the United States. These are called Sectional Aeronautical Charts, and California is covered by seven such sheets. Regional charts on the scale of 1:1,000,000 are also issued. Recently detailed planimetric maps (without contours) made

from aerial photographs, scale 1:10,000, have been issued covering an area around San Francisco Bay, the delta area west of Stockton, and the coast line from Los Angeles to San Diego. The Coast and Geodetic Survey does not issue topographic quadrangles.

PRESENT STATUS OF GEOLOGIC MAPPING

There is no special agency which has been assigned only to the mapping of geology. There are many different kinds, shapes, and sizes of geologic maps in California prepared for various purposes and on various bases. Most of them are not published on a topographic base. Many excellent geologic maps of irregular areas were made for special use, but not as all-purpose maps that might serve various users. The distribution of these maps is shown on the accompanying index map.

*Principal geologic mapping agencies**

- United States Geological Survey
  - Geologic Branch
  - Water-Supply Branch
- California State Division of Mines
  - Geologic Branch
- Departments of Geology of Universities in California
  - University of California
  - University of California at Los Angeles
  - Stanford University
  - Pomona College
  - California Institute of Technology
  - University of Southern California
- Departments of Geology of Universities outside of California
  - University of Washington
  - Yale University
  - Harvard University

Principal geologic map publishing agencies **

- United States Geological Survey
- California State Division of Mines
- University of California Press
- Geological Society of America

Detailed geologic mapping of a quadrangle requires careful examination, in the field, of every portion of the area. This generally involves years of study by a geologist trained in stratigraphy, paleontology, petrology, mineralogy, geologic structure, and topography. The boundaries between rock units are drawn in the field by plotting on the printed topographic quadrangle. The dip and strike of strata, foliation, or veins are generally indicated on the map. Structural lines, faults, and folds are determined and plotted. The field work is supplemented by laboratory and microscopic investigations of rocks, minerals, and fossils. Features of economic concern, such as the development of mineral deposits, are indicated on the map and described in the report; this is generally done after the mapping of the rock formations has been accomplished.

For many years the Geologic Branch of the United States Geological Survey carried on a regular program of mapping geology on quadrangles; the result was the well-known folio (now discontinued), which contained

* All these agencies have contributed geologic maps made on the topographic quadrangle base.

** All these agencies have published colored lithograph geologic maps of California printed on the topographic quadrangles as a base.

colored lithograph maps, including both topography and geology on the same map. The Survey has more recently concentrated its efforts on special examinations, with maps, generally of much smaller areas than quadrangles. The folio work, which in California covers only the northern Sierra Nevada and three small areas in the Coast Ranges, is still regarded as outstanding, and the most useful geologic work of any done in the State. It is now, however, out of date, in need of revision, and in need of re-mapping on a much larger and more accurate topographic base.

Mapping geology on topographic quadrangles has been carried on for a number of years by geological departments of universities, their faculty members and graduate students. The University of California has in recent years been especially active in this work, some of which has been published. The recently issued *Geologic Map of the San Benito Quadrangle* and the *Geologic Map of the Jamesburg Quadrangle* (in press), by the California State Division of Mines, are examples. These maps follow very closely the pattern of the early folio work, but are done in greater detail and on a larger-scale base. Plans for the publication of more such quadrangles are under way in the Division of Mines.

Some of the quadrangles that have been mapped geologically (by various persons associated with different universities), but not yet published, are:

Completed or nearly completed (scale 1:62,500)

Adelaida
Antioch
Bradley
Bryson
Cape San Martin
Carquinez
Copperopolis
Mare Island
Nipomo
Paso Robles
Piedras Blancas
Point Reyes
San Miguel
San Simeon
Vacaville

Completed or nearly completed (scale 1:125,000)

Cholame
Napa
Priest Valley

Under way (scale 1:62,500)

Blairsden
Branch Mountain
Carbona
Indian Gulch
Lodoga
Monterey
Morgan Hill
Venado (Wilbur Springs)
New Almaden
Reiff
Salinas
San Juan Bautista
Soledad
St. Helena (Pope Valley)
Tesla
Ventura

NATURAL PROVINCES AND MINERAL DISTRIBUTION OF CALIFORNIA

The distribution of mineral deposits in the State is shown graphically and in colors on a map accompanying this report. A three-fold classification has been made: (1) metals; (2) non-metals; (3) oil and gas fields, and areas of sediments explorable for oil and gas. The distribution of these three classes of minerals shows that they have a definite grouping or arrangement which conforms with the recognized natural provinces of California. Since the natural provinces represent an outgrowth of the

geologic evolution of the State and are distinguished by peculiar geomorphic or physiographic features, it is not surprising that the distribution of the mineral deposits is controlled by these provinces. A still greater distinction between provinces would be brought out if the mineral deposits were further classified by kinds of minerals.

Natural provinces of California
(Physiographic or geomorphic provinces)

Coastal Region
- Coast Ranges
- Transverse Ranges
- Peninsular Ranges
- Great Valley

Desert Region
- Mojave Desert
- Colorado Desert
- Basin Ranges

Mountain Region
- Sierra Nevada
- Klamath Mountains

Plateau Region
- Cascade Range
- Modoc Plateau

The Coastal Region contains all of the oil fields, many strategic mineral deposits (quicksilver, chromite, manganese, and magnesite), and numerous non-metallic deposits and structural materials. The Desert Region contains mineral deposits of many sorts and an immense potential mineral wealth yet to be developed, including both metals and non-metallics. The Mountain Region contains the world-famous gold belt and many other mineral resources, and in addition hydro-electric power of enormous capacity which can be used for metallurgical development. The Plateau Region contains mineral deposits of lesser importance than those of the other provinces.

DEARTH OF MAPS IN THE MINERAL PROVINCES

In comparing the mineral distribution map with the index to topography and geology, it is clearly seen that preference has always been given to agricultural areas. In some places these areas have included oil and gas fields. The vast mineral provinces of the State, however, have been, for the most part, neglected. Maps of small scale, now out of date, are about the only ones available to the metal mining industry. This condition should be corrected, so that the mineralized areas would be supplied with adequate maps, both topographic and geologic, of sufficiently large scale to be of practical use. With adequate maps, great strides would undoubtedly be made in the expansion of the mineral industry.

The Multiplex method now employed for drawing contours on topographic maps from aerial photographs, makes it possible to prepare contour maps in great detail and on a large scale of the most mountainous and inaccessible regions. No longer is there any valid excuse for omitting the mountain areas from the mapping program.

Geologic mapping is dependent upon the availability of adequate topographic maps. If contour maps of high quality are made of the mountainous and more inaccessible areas, this will only be a challenge to the geologists, who would consider it a privilege to map the rock formations where they are best exposed. In such areas will come the discoveries of potential mineral wealth to build the future industries of the State.

GEOLOGY OF THE JAMESBURG QUADRANGLE, MONTEREY COUNTY, CALIFORNIA*

By William Morris Fiedler **

OUTLINE OF REPORT

* Dissertation submitted in partial satisfaction of the requirements for the degree of Doctor of Philosophy in geology, in the Graduate Division of the University of California. Heavy mineral analyses and petrographic descriptions of specimens have been omitted, but may be consulted in the original thesis on file at the University of California. Manuscript submitted for publication May 31, 1944.

** Geologist, Jones and Laughlin Ore Company, Pittsburgh, Pennsylvania.

ABSTRACT

The Jamesburg quadrangle lies in the Santa Lucia Range of the central California Coast Range system. The lithologic units which have been mapped are, from oldest to youngest: Sur series (age unknown), comprised chiefly of meta-sedimentary quartzose schists and gneisses with some quartzite, marble, and meta-basic igneous rocks; Santa Lucia granitic intrusives ranging from acid to basic in composition (probably pre-Jurassic in age); serpentinized ultra-basic plugs and dikes (Jurassic?); sandstone (middle Eocene); Vaqueros-Temblor sandstone with minor siltstones and conglomerates (lower-middle Miocene); Monterey formation, chiefly organic and chemical cherts and shales (middle-upper Miocene); San Pablo sandstone (upper Miocene); Quaternary deposits, terrace gravels, stream alluvium, alluvial fans and landslide accumulations. Volcanics have been recognized in both the Vaqueros-Temblor and the Monterey formations.

The metamorphism of the Sur series is chiefly regional, but with superposed thermal effects related to the emplacement of the Santa Lucia batholithic mass which is made up of a series of smaller intrusive bodies of differing composition. Minor regressive and dynamic metamorphism is evidenced in all of the crystalline rocks. The Sur series is believed to have been subjected to open folding and faulting in pre-Jurassic time. The structures then formed may have guided the major Plio-Pleistocene deformation.

Both structurally and physiographically the area can be divided into three major northwest-trending belts: the mountainous Santa Lucia belt to the south; the low, open Tularcitos belt crossing the center of the area; and the rugged Sierra de Salinas to the north. A small part of Salinas Valley is also included within the limits of the quadrangle. Tertiary sediments are most abundant in the Tularcitos belt where they have been compressed into broad open folds complicated by later faulting. In the Santa Lucia belt, isolated blocks of sediment have been faulted down into the basement rocks along northwest-trending faults which are the major structures throughout the entire quadrangle. These are cut and displaced by smaller cross-faults. Crystalline rocks make up the entire Sierra de Salinas belt, in which few structures have been recognized.

INTRODUCTION

Location and Geography of the Area

The Jamesburg quadrangle comprises an area of nearly 250 square miles lying between latitudes 36° 30′ and 36° 45′ and longitudes 121° 30′ and 121° 45′. The area is included within the Santa Lucia Range in the Coast Range system of central California. Its location is shown by the index map.

The region is sparsely populated; there are summer cottages at Camp Stephani in the northwestern part of the quadrangle, but there is no post office within the area. Cattle raising is the chief industry, but the dude ranch and resort business is increasing in importance yearly. The inhabited section is limited to a 3-mile strip extending southeastward from the northwest corner of the quadrangle. Here the ranches, hotels, resorts, and summer cottages are located. South of this strip, in the heart of the mountains, the only inhabitants are the week-end sportsmen who fish trout and hunt deer, wild boar, or mountain lion; and the fire guards and lookouts who protect the Santa Barbara National Forest land. North of the central strip the only inhabitants are occasional cowboys during round-up season.

There are only two highways in the area, one extending the entire width of the area through the heart of the inhabited strip and the other merely a side loop, following Cachagua Creek and crossing Tularcitos Ridge. The only other road, save for the ranch roads in the northeast, is an old coolie-built route* from Jamesburg across the crest of the range to Tassajara Hot Springs Resort in the Lucia quadrangle to the south.

Trails are maintained by the Forest Service, but they are few and far between and much of the area has no trails at all, having been designated as a ''primitive area'' by the government.

The quadrangle lies within the Mediterranean climate zone. Wet, cool winters, and hot, dry summers are characteristic.

Buck brush, chamise, manzanita, and scrub oak form the chaparral cover which is the most characteristic feature of the Mediterranean evergreen forest in this region. The brush cover is continuous over large areas and often so dense as to be almost impenetrable. Madrone, sycamore, willow, and live oak are common and there are a few stands of pine and redwood. In the central inhabited area wild oats cover most of the low slopes.

On the whole the region is one of rugged topography and is deeply and intricately dissected. Only in the central belt are there large flat areas. The maximum relief is nearly 5,000 feet.

The major drainage basins are those of the Sur, Little Sur, Carmel, and Salinas Rivers. The last-mentioned stream does not occur within the limits of the quadrangle. To the southwest many of the streams are permanent, but to the northeast not even the large streams flow in summer.

Present Investigation

The field work which served as the basis for this report was carried on during the summers of 1939, 1940, and 1941, and at various intervals of short duration during the fall and spring of the same years. Laboratory work was carried on in conjunction with the field studies, and continued during 1942.

The 1921 edition† of the United States Geological Survey topographic sheet of the Jamesburg quadrangle, Monterey County, California, was used as a base for the field mapping. This map, on a scale of 1:62,500, or approximately one inch to a mile, proved very satisfactory in the field and, except for a few small areas, accurate as well.

---

* This is now a fairly good mountain road, very scenic, giving access to the interior rugged country. *O. P. J., August, 1944.*

† The culture has been revised and a new edition issued of the Jamesburg quadrangle published in 1940 by the Corps of Engineers, U. S. Army.

2—36585

The writer was assisted in the field during part of the summer of 1939 by Mr. Benjamin Douglas and during the summer of 1940 by Mr. Donald Fawcett.

Acknowledgments

Thanks are due Professor N. L. Taliaferro, who suggested the area to the writer and gave aid and constructive criticism generously throughout the course of the investigation; to Professor B. L. Clark for the determination and interpretation of the fossil collections; and to Professors L. M. Gould of Carleton College, F. F. Grout and R. A. Stauffer of the University of Minnesota, C. A. Anderson, H. Williams, and W. A. Setchell of the University of California, all of whom checked the results of the work and offered valuable advice and criticism.

The residents of the region extended innumerable courtesies during the course of the work. To Mr. William Lambert and Mr. William Foster the author is especially indebted for many kindnesses. Dr. J. Lonsdale, Mr. Girard, Miss Blomquist, and Mrs. Cahoon, to mention only a few of the others, aided the writer greatly during his months in the field.

During the course of the work, the author's wife gave constant encouragement and aid, especially in the preparation of plates.

The Minnesota Academy of Science awarded an A. A. A. S. research grant which helped defray the expenses incident to the final laboratory studies and the preparation of the report. Mr. Olaf P. Jenkins added valuable suggestions and criticism while editing the manuscript for publication.

Previous Geologic Work

Little geologic work has been done in the Jamesburg quadrangle except that by Herold (35) in connection with his mapping of the Salinas quadrangle. Save for an abstract covering the geology of both areas (Herold 39), the only report on this work has been in two brief papers (Herold 36 and 37) dealing with special and local features of the geology. An unpublished map by Rumbley (30) covers the northern half of the Jamesburg quadrangle. Information in the files of oil companies is the only other record of geologic work in this area.

Trask (26, p. 122) gives an excellent summary of the meager literature on the Santa Lucia Mountains in his report on the Point Sur quadrangle which adjoins the Jamesburg on the west. Reiche (37, p. 115) adds a few more recent citations in his report on the Lucia quadrangle, which lies south of the Jamesburg quadrangle. The Monterey (Beal 15), Salinas (Herold 35), and Soledad * (Schombel 40) quadrangles, northwest, north, and east, respectively, of the Jamesburg sheet, are discussed in unpublished masters theses, in each of which some additional literature is cited.

DESCRIPTIVE GEOLOGY

The formational units shown in the stratigraphic column (fig. 5) range in age from Paleozoic (?) to Recent. In order from oldest to youngest they include: the Sur metamorphic series; the Santa Lucia granitic plutonics; Jurassic (?) serpentinized ultra-basic intrusives; a

* Ed. Note: An abstract of the thesis by Mr. Schombel, *Soledad Quadrangle*, has been published with geologic map, columnar section, and structure sections, in Bulletin 118, *Geologic Formations and Economic Development of the Oil and Gas Fields of California, pp. 467-470, California State Division of Mines, 1943.*

middle Eocene sandstone; the Miocene series of sediments including the Vaqueros-Temblor sandstones (with several units doubtfully assigned to this age), the Monterey siliceous and limy shales, and the San Pablo sandstones; and Quaternary stream alluvium, terrace gravels, alluvial fans, and landslide accumulations. Included in these groups are several volcanic units in the Vaqueros-Temblor and Monterey formations, and possibly meta-volcanics within the Sur series.

Sur Series

The oldest rocks in the quadrangle are a great series of metamorphics: schists, gneisses, quartzites, meta-basic igneous rocks, and marbles. Trask (26, p. 134), applied the name "Sur series" to this unit in the Point Sur quadrangle. The Jamesburg and Point Sur occurrences are continuous.

Heavy brush and soil cover and difficult topography have greatly complicated the study of the Sur series not only in the Jamesburg quadrangle, but in adjoining areas as well. Little if any detailed work has been done in this series. No stratigraphic sequence has yet been determined and the structure, thickness, and age of the series are still in doubt.

Distribution

The Sur series is the predominant formation in the Jamesburg quadrangle. All of the southwestern half of the quadrangle is occupied by this unit, except for two large areas of intrusives in the west and south, and small isolated patches of sediments scattered throughout the predominantly Sur terrain. To the northeast it makes up most of the Sierra de Salinas.

Lithology

Reiche (37, pp. 118-129) has made a detailed study of the lithology of the Sur series from material collected in the Lucia quadrangle which adjoins the Jamesburg to the south. The present study adds little new material except to lend support to his results and to expand their application.

Reiche (37, p. 118) subdivides the Sur metamorphic rocks into four major lithologic groups, which, in order of abundance in the Lucia quadrangle, are: (1) quartzose; (2) aluminous; (3) lime-rich; and (4) metamorphosed basic igneous. All of these types were found in the Jamesburg quadrangle. While the Jamesburg metamorphics are for the most part very similar to those of the southern quadrangle, one difference is strikingly apparent, namely, the very minor role of lime-rich rocks in the Jamesburg quadrangle. Correspondingly, aluminous and meta-basic igneous rocks are more common in the Jamesburg area. In both areas, however, the quartzose metamorphics are the most abundant type.

Detailed petrographic descriptions of representative specimens of the pre-Tertiary rocks are included in the unpublished thesis from which this report is taken. The thesis is obtainable at the library of the University of California, Berkeley.

Quartzose Rocks. The quartzose metamorphics include quartzites, and quartz-biotite schists and gneisses.

The quartzites are light in color, usually gray-blue, gray-green, or tan, fine-grained, vitreous, and thoroughly recrystallized to a mosaic texture, the grains of which under the microscope show undulatory extinction. Locally biotite partings occur within the quartzites.

In the field the quartzite layers are usually thin, a fraction of an inch to a few feet being the usual range in thickness. They occur mixed with other metamorphic types, frequently alternating with quartz-biotite gneisses. Not uncommonly, by increasing percentage of biotite, there is a gradation between these two types. While not particularly abundant they are widespread throughout the entire Sur area.

The quartz-biotite gneisses are the most common rock type in the quadrangle. Banding in these rocks is due primarily to the orientation of the biotite flakes, since the quartz-feldspar mosaic only rarely shows any directional arrangement. In general, though discontinuous, the biotite bands are evenly spaced and straight, but locally they are mildly contorted. Most of these rocks are finely banded gneisses in which the perfection of foliation varies with the amount of biotite. With increasing biotite they grade into quartz-biotite schists, and ultimately to aluminous biotite schists. Light gray is the most common color of the gneisses, in which the quartz and feldspar are usually far more abundant than the biotite. A small amount of garnet is usually present, commonly in small grains visible only in thin section, but occasionally as large megascopic grains up to 3 millimeters in size. Zircon and magnetite are almost always represented in section, the former usually as small seed-like inclusions in the biotite surrounded by pleochroic halos, but not infrequently as small prismatic crystals in quartz.

All of the quartzose rocks studied in thin section appear to be sedimentary in origin. Reiche (37, p. 119) reports several orthogneisses and such may be present in the Jamesburg quadrangle in minor amounts.

The quartz-biotite gneisses are abundant throughout the Sur area. To the northeast in the Sierra de Salinas the entire terrain is composed of these quartzose rocks. The uniformity of this metamorphic type in the northeast is in striking contrast with the rapid variations to the southwest in the Santa Lucia Range.

In the southern area the quartzose rocks are everywhere cut by aplite and pegmatite dikes and sills. The aplite intrusions are usually small, and often there is a complex network of such intrusives cutting quartzose rock in every direction. Frequently the aplitic stringers parallel the foliation to produce injection gneisses with coarse bands up to 2 centimeters in thickness. Usually, however, it is the aluminous metamorphics which are so injected.

Aluminous Metamorphics. Next in abundance to the quartzose rocks are the biotite and hornblende schists which comprise the aluminous metamorphics. Included in this group are many types with weakly gneissic structure, but the most common type is lepidoblastic biotite schist which differs from the quartzose rocks already described chiefly in the higher percentage of biotite. Such rocks while abundant are rarely found unaffected by intrusion. By lit-par-lit injection they have almost universally been changed to gneiss. Injection gneisses with bands usually 2 to 5 millimeters in width are common throughout the Sur series, especially in the Ventana country.

As a rule the gneiss has been formed by injection of magmatic material between the planes of schistosity; however, the igneous bands are occasionally irregular and have gradational contacts with the schist, suggesting replacement. In the neighborhood of the Santa Lucia contact, igneous rocks are found with abundant oriented xenoliths of biotite schist, some of which have large feldspar porphyroblasts. Such occurrences, found north of Ventana Cone and in the Rattlesnake Creek area, are suggestive of "granitization." Nowhere, however, were true igneous rocks found to grade through this phase into schistose metamorphics.

While in most of the area the biotite schist shows straight and even schistosity, locally it is severely crenulated. Wollastonite and cordierite are developed locally in the injected schist.

Metamorphosed Basic Igneous Rocks. Plagioclase - hornblende gneiss and amphibolite are common throughout the southern half of the area and are believed to represent metamorphosed basic igneous rocks. For the most part they are weakly gneissic in texture, but locally foliation is well developed. Both in hand specimen and thin section many of these rocks look much like igneous rock, and some were at first mapped as phases of the Santa Lucia intrusives. Nor is there any reason to believe that some of these rocks may not represent a basic phase of the Santa Lucia intrusive cycle. However, pronounced foliation in some of the rocks and mild foliation in many, suggest that they are older than the Santa Lucia intrusives at least in part, having suffered the same metamorphism as the other Sur rocks. The hornblendites known to be a part of the Santa Lucia series do not show any metamorphic effects, except of a mild dynamic and regressive type.

Only one of the rocks studied in thin section was a pyroxene ultrabasic, but many of the amphibolites may have been derived from pyroxenites.

This metamorphic type is most abundant in the southern part of the quadrangle in the Ventana Cone area where with the aluminous injection gneisses it may even surpass the quartzose types in abundance. Although widespread throughout the other Sur areas, rocks of this type are not abundant.

Lime-Rich Metamorphics. Marbles are not common in the Jamesburg area. Both to the west and southwest, Trask (26, p. 131) and Reiche (37, p. 123) have found numerous large marble lenses which they have mapped separately from the other Sur types. In the Jamesburg quadrangle not only are marbles rarely encountered, but they are small and discontinuous. Usually they are 10 feet or less in thickness and can be traced along their strike only a few hundred feet at most. Only five marble lenses were found that were large enough to indicate on the geologic map.

The marbles in the Jamesburg quadrangle are notably pure. They vary from fine to extremely coarse in grain and from white to gray and gray-blue in color. Almost always there is a little graphite present, and locally pyroxenes are present. The marbles are completely recrystallized and no evidence of organic life, other than the graphite, was found.

The marble lens in Trampa Canyon has been mineralized and was mined for copper at one time. Occasionally skarns (contact-metamorphic mineralized areas, also known as tactite) are developed in the marbles where they are in contact with Santa Lucia intrusives.

Distribution of Lithologic Types

No stratigraphic sequence has been established within the Sur series, but in a general way there is an areal differentiation in the distribution of the lithologic types discussed above. The most striking feature is the difference between the Sur series in the Sierra de Salinas and in the Santa Lucia Mountains to the south and west. The persistence of quartzose rocks throughout the entire northeastern area is in marked contrast to the rapid variations in the southern area.

All of the metamorphic types described above, with the exception of the marbles, are common throughout most of the southeastern half of the quadrangle. The aluminous metamorphics and injection gneisses are most abundant in the southern third of the quadrangle and the quartzose rock seems to decrease to the south, although it is always the predominant type.

South and west, beyond the limits of the area under discussion, marble becomes an important element in the Sur series, and the metabasic igneous rocks again diminish in amount.

Thus it appears that in the basin of Sur deposition, arenaceous and argillaceous sediments were deposited to the north and east while the limestones were accumulating to the south and west; and that igneous activity was in large part confined to the central portion of the area (the southern part of the Jamesburg quadrangle and the northern parts of the Lucia quadrangle).

Structure and Thickness

Schistosity in the metamorphics parallels the original bedding. At no place in the area where limestone or quartzite served to establish the original bedding planes, was the foliation found to cut across the older structure. Mapping of the schistosity can, therefore, be used to interpret the attitude of these beds.

Over large areas the attitude of the metamorphics remains essentially constant. Trask (26, p. 127) and Reiche (37, p. 118) agree that the whole series may be homoclinal with a northwest strike and northeast dip. Such is the predominant attitude within the Jamesburg, as well as the Point Sur and Lucia quadrangles. However, there are variations, especially in dip, and folding may not be precluded until much more detailed work has been done in some portion of the Sur area. In most of the area lack of outcrops and extremely rugged topography make detailed work impractical especially during the course of such studies as have been carried out to date in the Santa Lucia Mountains.

Although the author was impressed by the general regularity of attitude in the metamorphics, nevertheless, when more and more readings were plotted, notable variations all through the Sur areas became apparent. A few folds are shown in the accompanying cross sections, but because of the lack of data, the sections are diagrammatic. Trask (26, p. 127) and Reiche (37, p. 156) have both mapped broad local folds in the metamorphics, but to date no detailed work has been done to show the true nature of the structures.

The lack of any recognizable sequence within the Sur series makes the determination of structural details most difficult, and even known faults are lost when traced into Sur areas. However, the presence of many shear zones all through the southern half of the Jamesburg quad-

rangle leads to the conclusion that large faults, and very probably an intricate fault pattern, might be worked out within the areas occupied by the Sur metamorphics. A few faults have been traced across such areas in the course of the present work, but only with the expenditure of much time and effort, and only where the faults had first been recognized in some sedimentary area.

The evidence of broad open folding complicated by later faulting seems conclusive. In some locations the dips change rapidly, as in the region south of Church Creek, where within half a mile dips from 37° to 90° were obtained. Possibly this is due to faulting, but no evidence of shearing could be found, nor was there any evidence of isoclinal folding here or in any other part of the quadrangle.

Small folds are common in the metamorphics. In several widely separated areas, minor folds, only a few tens of feet across, were seen in the Sur schist and gneiss. A whole series of such folds is beautifully exposed in the creek in the SW$\frac{1}{4}$ sec. 28, T. 18 S., R. 3 E., M. D. On the north bank of upper Chupines Creek, below the Tertiary sandstone, a series of open folds a quarter to half a mile wide is well exposed on the valley wall.

In view of all these complications, uniform dips seem remarkable indeed, but may be accounted for by the broad nature of the major folds and the thickness of the series.

Because of the uncertainty as to structure within the Sur series it seems unreasonable to attempt to estimate its thickness. Trask (26, p. 128) estimates 5,000 feet, Reiche (37, p. 118) 10,000 feet, and both show considerably greater thicknesses in their cross sections. Assuming homoclinal dips in some of the little-known Sur areas, the thickness may reach 15,000 feet or more in the Jamesburg quadrangle, but allowing for unrecognized folding and faulting, the thickness may be assumed to be much less. The fact that uniform dips are met with over large areas despite lack of evidence of isoclinal folding does necessitate that the formation have considerable thickness. On the whole 5,000 feet does not seem an unreasonable estimate.

Origin and Metamorphism

Most of the metamorphics are of sedimentary origin and are believed to have been initiated as a great series of sandstones, shales, and limestones. From the distribution of types discussed above, an eastern source is suggested. It would seem that while the parent series was predominantly sandy throughout, the sandstones were most abundant to the northeast, grading through shaly sandstone and shale (now aluminous metamorphics) to limestones in the south and west. However, marbles, probably members of this same series, do occur abundantly in the Gabilan Range to the northeast (Herold 35, p. 110; Becker 88, p. 16). Much more work will be needed to check this conclusion, but the present sketchy information is at least suggestive of an eastern source.

The relation of the basic igneous rock to the sedimentary sequence is as yet uncertain. For the most part their contacts seem to parallel the schistosity and bedding of the metamorphics, suggesting either sills or flows. No relic textures such as one might expect to find in metamorphosed flows have been noted in the area, and for this reason the units are believed to be intrusive. Locally the basic bodies cut the schistosity in the manner of dikes. The distribution of the metamorphosed basic

igneous rocks suggests that the volcanic activity centered in the midst of the sedimentary area—the southern part of the Jamesburg quadrangle and farther south in the Lucia area.

Reiche (37, p. 130) describes the metamorphism of the Sur series as follows:

> "It appears that the Sur series has undergone, first, a thorough regional recrystallization of the sort commonly known as load metamorphism, and second, a relatively local and unimportant thermal metamorphism consequent upon the emplacement of the plutonic intrusives. With this latter change certain pneumatolitic effects are presumably to be connected. Finally a very minor dynamic alteration has affected the entire body of the Sur series and is related probably to the orogenic processes of late Mesozoic and of Plio-Pleistocene time."

The study of the Sur rocks of the Jamesburg quadrangle supports this statement. The complete recrystallization of all specimens studied, the lack of any contact aureole or any gradation in the degree of metamorphism in the neighborhood of intrusive contacts, and the lack of any isoclinal or even closed folds precludes both thermal and dynamic metamorphism as the dominant process in the change from sediments to crystalline rocks.

The recognition of cordierite, the suggestion of granitization, the discovery of more wollastonite and scapolite, and the very marked abundance of injection gneiss, some of which is apparently of replacement origin, suggest rather more widespread thermal effects of the intrusion than outlined above by Reiche, but that these effects are secondary to load metamorphism is certain.

The same evidence as that reported by Reiche (37, p. 131) for the later and superficial dynamic metamorphism and start of regressive changes was found in the Jamesburg area. Strain shadows in the quartz, bent and broken feldspar twins, cross-twinned calcite, and even cataclastic borders in some rocks evidence widespread dynamic metamorphism.

Chloritic alteration of biotite, sericitization of feldspar, and the development of amphibole from pyroxene evidence regressive metamorphic changes.

Age

No information obtained within the Jamesburg quadrangle serves to answer the riddle as to the age of the Sur series. Within the area of the present report the oldest sediments lying depositionally on the basement rock are the Miocene Vaqueros-Temblor sandstones. The Eocene is bounded by fault contacts, and if some of the questionable Vaqueros-Temblor units are older than Miocene their age is not known. Hence we know only that the Sur series is pre-Miocene. Abundant evidence has already been cited proving the intrusive relations between the plutonics and the Sur metamorphics, and the Sur series is definitely pre-Santa Lucia, but the age of this intrusive is unknown. By largely negative evidence, to be discussed in a later section, the Santa Lucia quartz diorite is usually indicated as pre-Jurassic.

No fossils have ever been reported from the Sur series in the Santa Lucia mountain area. The crinoid stems reported by J. P. Smith (16, p. 25) from the Gabilan limestone of Fremont's Peak have never been relocated nor checked and the Gabilan limestone has not definitely been correlated with the Sur limestones.

Most writers believe the Sur series is Paleozoic; lacking any definite evidence, it is here included doubtfully in the Paleozoic.

Santa Lucia Quartz Diorite

Lawson (93, p. 9) applied the name ''Santa Lucia'' to the porphyritic granite near Carmel Bay. Trask (26, p. 134) states that this granite is a differentiate of the main quartz diorite intrusive of the Point Sur quadrangle, retains Lawson's name, and applies it to the whole intrusive series which is continuous from this area into the Jamesburg quadrangle.

Distribution

Within the Jamesburg quadrangle there are three major areas of granitic intrusives. The largest of these is in the western part of the area and extends from San Clemente Creek south to the Ventana Cone region, being broken south of Uncle Sam Mountain by the Church Creek fault. A second large mass extends through the northern part of the area, flanking the Tertiary syncline and occupying Long Ridge and the region to the north, much of Tularcitos Ridge, and the southwestern margin of the Sierra de Salinas. Along the southern map margin a tongue of intrusive occupies the crest and east slope of the ridge between Tassajara and Redwood Creeks. In addition to these three major units there are numerous small areas of intrusive rock. Some of these have been brought up by faulting as, for example, that near the northwest corner of the map and that between Chupines and Klondike Canyons. Others appear to be projections, only the largest of which have been mapped, of the uneven roof of the batholith. One of these occurs in the area between Pine and San Clemente Creeks.

Dikes are abundant throughout most of the Sur terrain, but are too small to indicate on the geologic map.

The separation of the Santa Lucia quartz diorite and Sur series is not easy. Almost all of the metamorphics contain intrusives in the form of dikes, sills, and probably larger bodies as well. The possibility of granitized sediments and the presence of metamorphic inclusions in the intrusive further complicate the picture. As a result the contacts shown on the map are only approximate. In general the areas mapped as Santa Lucia are free from metamorphic materials, but within the areas mapped as Sur series there are many units of intrusive rock, only the largest of which have been separately mapped. The gradational contact zones have been included with the Sur series, and the distribution of the Santa Lucia intrusives shown on the geologic map is, therefore, a minimum. Detailed mapping might greatly enlarge the areas already shown and add numerous small new areas.

The abundance of dikes and injection gneiss throughout the entire southern part of the quadrangle suggests that the intrusive is nowhere far beneath the surface. Locally granitic material appears in the deeper canyons within the Sur areas and commonly dikes and injection gneiss increase in abundance in the canyons. Reiche's suggestion (37, p. 132) that detailed mapping would show ''many canoe-shaped outcrops of plutonic rock in the bottom of the deeper canyons'' in the Lucia quadrangle indicates that the intrusive may be even closer to the suface to the south. This principle has been applied in the construction of the cross sections.

In the southwestern part of the Jamesburg quadrangle most of the highest parts of the Santa Lucia Range are granitic, probably because

of the superior resistance of the massive igneous rock. All three Ventana peaks as well as Uncle Sam Mountain are composed of igneous rock. Locally this has led to the anomalous occurrence of granitic debris on ridge crests and Sur outcrops in the valleys below.

Lithology

Within the intrusive mass there are abundant rock types, which vary in texture and composition. Examples of a whole series of granitic rocks have been found. Granite, quartz monzonite, granodiorite, quartz diorite, and diorite have been recognized, and in addition a few small basic plugs have been discovered. The possibility that some of the basic dikes included in the Sur series may be a part of the Santa Lucia has already been noted.

Except for the basic rocks, all of the plutonic types are intimately associated with one another and may represent a series of intrusives which together form the Santa Lucia batholith. Some types may represent marginal phases of the batholith effected by assimilation or ''granitization.'' Time was not available to attempt separate mapping of the igneous types and it is doubtful whether such separation could be made in this area. Locally the alternation of type is most rapid. In Rana Creek, for example, a porphyritic hornblende-biotite diorite, a eugranitic* hornblende diorite, and a eugranitic biotite-quartz diorite, all outcrop within a mile of each other. Such rapid alternation is not common throughout the area, but is widespread. It is only possible to make broad generalizations as to the distribution of the various lithologic types.

Quartz diorite seems to be the predominant igneous type in the region as a whole. The major and central portion of the two largest Santa Lucia areas are of eugranitic, medium- to coarse-grained biotite-quartz diorite. Although usually massive it occasionally shows gneissic texture (believed to be of primary origin), as a result of the alignment of mafic constituents. The plagioclase varies slightly in composition, but remains within the limits of andesine; the biotite is usually greenish brown in color and moderately pleochroic. Zircon, magnetite, and apatite are commonly present as minor accessories.

Granodiorite closely approaches quartz diorite in abundance and is widespread throughout the area. Usually it appears to flank the quartz diorite and to occur between it and the metamorphics. Locally, however, it comprises most of the igneous area. In the west, from San Clemente Creek south to the Ventanas the granodiorite is abundant, especially along the eastern margin of the igneous mass. Here it is typically porphyritic with large microcline phenocrysts up to 2 centimeters in size in a medium-grained groundmass of quartz, feldspar, and biotite. The plagioclase is usually andesine, but occasionally oligoclase. Much of the quartz is bluish in hand specimen and the feldspars are usually kaolinized to a dusty tan color. The rock is almost everywhere deeply weathered, and fresh samples are difficult to find.

Along the southwestern margin of the Sierra de Salinas south of Agua Mala Creek granodiorite is again the most common rock type. Here it is eugranitic and medium-grained, and has about the same mineral content as the porphyritic type.

* "Eugranitic" refers to ordinary granitic texture, as distinguished from porphyritic, aplitic, or pegmatitic.

Granite, while not abundant, is widespread, especially in the form of dikes. In some areas the granodiorite appears to grade to true granite, some of which is porphyritic, some coarse-grained and eugranitic. In the field it too is deeply weathered and looks so much like the granodiorite that it is often impossible to distinguish the two. The margins of the large intrusive mass in the west appear to be largely granite. Long Ridge contains much coarse eugranitic granite. Elsewhere, while not uncommon, it is usually minor in amount.

Diorite is not an abundant rock type, but again is widespread in occurrence. It is most important in the Ventana area. Often melanocratic and sometimes weakly gneissic, it looks in hand specimen and thin section much like the plagioclase amphibolites included with the Sur series, some of which, as already noted, may well belong with the Santa Lucia series as an early phase of the intrusive cycle.

Coarse basic intrusives are occasionally found. They are small irregular masses a few hundred feet in diameter, the margins of which cut across the regional schistosity. Composed chiefly of large amphibole crystals up to an inch and a half in size, the rocks are lustrous and dark black in color. In thin section the rock was found to be a basic gabbro in which the pyroxenes had been changed to amphibole. A little labradorite is present. The relation of these basic plugs to other members of the intrusive series was not determined in the field, but they are believed to be an early phase of the Santa Lucia magma and may have initiated the intrusive cycle in this area.

Dikes

Dikes are abundant throughout the area of crystalline rocks. Aplitic, pegmatitic, granitic, and basic dikes have been found.

The basic dikes are of two types: amphibolites, which have already been discussed in connection with the Sur series, since many of them show metamorphic effects, and serpentinized dikes which are believed to be Jurassic in age and will receive attention in a later section.

Aplites are the most abundant type of dike in the Jamesburg area and are widely distributed throughout the Sur series. They range from thin stringers less than an inch in thickness to large dikes 10 feet or more in width. They often form exceedingly complex patterns. Locally, as already noted, the small aplitic injections are closely spaced and form extensive injection gneisses.

Most of the aplites are fine-grained and light gray or tan in color, with typical even-grained allotriomorphic texture. They consist chiefly of quartz and orthoclase and minor amounts of oligoclase and biotite. Garnet is occasionally visible in hand specimens.

So abundant are these aplite dikes and so intricate is their pattern that the proximity of the batholithic mass seems assured and where not outcropping it must be reasonably close to the surface below the metamorphics. For this reason the Santa Lucia batholith has been shown below the Sur series in the structure sections.

In the Sierra de Salinas, dikes are not abundant and the uniformity of the metamorphic type in this region may be due, in part at least, to the absence of complicating igneous activity. Here the batholith may be far below the surface, but even close to the exposed igneous contact there are few dikes.

Pegmatites are not as abundant as aplites, but are none the less widespread. Although usually only a foot or two in width some reach a thickness of 15 feet, as for example, those exposed in upper Anastasia Canyon. The large pegmatites are remarkably uniform in appearance and composition. Very low in quartz content, they are composed chiefly of white feldspar, usually kaolinized and iron-stained to a dusty tan, and large books of biotite up to 4 centimeters across. The smaller pegmatites, though finer grained, are of similar composition. Occasionally quartz-rich pegmatites do occur, but they are exceptional and are always small.

Granitic dikes, both true granites and diorites, occur sporadically throughout the southern half of the quadrangle within the Sur terrain. The more basic varieties occur chiefly in the southwest, the acid in the north. They are fine-grained even granular, and apparently aschistic* offshoots of the parent magma.

One last type of intrusive may be mentioned, namely quartz veins. Widespread though not abundant in the Sur terrain, they were apparently derived from the Santa Lucia magma chamber. Although most of the veins are small, some are as much as 10 or 20 feet in width. One large vein can be traced discontinuously from the eastern margin of the map for 5 miles along the southwest side of the crest of the Sierra de Salinas. Most of these quartz veins are composed entirely of massive white bull-quartz. Occasionally a little pyrite is found in these veins, but usually they are completely barren. Many have been prospected, but so far as is known, none of these prospects have proved successful.

Age

The Santa Lucia quartz diorite is clearly younger than the Sur series. Dikes and stringers from the intrusive enter the metamorphics, and locally, thermal metamorphic effects have been superposed upon the earlier load metamorphism as a result of the intrusion. Lit-par-lit injection has led to widespread development of injection gneisses. Despite the widespread effects of the intrusive upon the Sur rocks, at no place could stringers or dikes be traced uninterruptedly from the Sur series into the main Santa Lucia mass.

The oldest rock lying depositionally on the intrusives is the Miocene Vaqueros-Temblor sandstone, which locally has a basal conglomerate comprised largely of Sur and Santa Lucia debris. The serpentine bodies, while younger than the granitic intrusives, have not been accurately dated, but are believed to be Jurassic in age. Within the Jamesburg quadrangle, then, the Santa Lucia intrusives are definitely pre-Miocene, and probably pre-Jurassic.

In adjoining areas (Trask 26; Reiche 37) Cretaceous sediments were deposited upon the intrusive so that the pre-Cretaceous age of the Santa Lucia is assured. Although the Jurassic in these areas is everywhere in fault contact with the intrusives, the lack of metamorphic effects in the sediments and the prevalence of igneous debris in the standstones suggests, but does not prove, the pre-Jurassic age of the Santa Lucia quartz diorite.

* Offshoots of the parent magma that are similar to it, and not differentiated in composition from it, are said to be "aschistic."

Serpentine-Jurassic (?)

Distribution

The serpentine plugs and dikes constitute one of the most interesting geologic features of the area. Enough of these bodies have been mapped to show a striking grouping in distribution. For the most part the serpentine is concentrated in two narrow belts. One of these is along the Blue Rock fault, in the northwest and west-central rectangles; the other is along a narrow zone, less than a mile wide, extending from the Sur River northeast for 10 miles to a point beyond Bear Trap Canyon. Within these two zones 19 serpentine bodies have been found. Only two others have been mapped within the limits of the quadrangle, but others may be present.

The first belt may be explained by assuming that the fault movements created a zone of weakness along which intrusion took place. No explanation can be offered for the second zone, which trends almost at right angles to the prevailing structural features of the area.

Lithology

The largest of the serpentinous bodies is that on Pine Ridge. Here the outcrop is about half a mile long and a quarter of a mile wide, elongated in a northeasterly direction at right angles to the structural trend. Apparently steep-walled, the body is believed to be a plug. No shearing is evident in the surrounding rock, but exposures are limited. The outer margins of the plug itself are intensely sheared and much more thoroughly serpentinized than the massive interior, which is composed of a relatively fresh, fine-grained, black lherzolite showing only minor serpentinization. The gradation from fresh lherzolite to sheared serpentine is by no means uniform from core to margin, and locally the fresh rock appears to extend to the exposed margins of the plug.

Next in size among the serpentine bodies are the five small plugs along the Blue Rock fault. Three occur on the ridge south of San Clemente Creek, one on Blue Rock Ridge, and one in Rattlesnake Creek. These masses are all quite similar in appearance and structural relationships. All occur in the midst of the sheared crystalline rocks and apparently were squeezed up along the fault zone. All are much more extensively altered than the Pine Ridge plug. No fresh lherzolite was seen, but relics of amphibole, pyroxene, and olivine in the least-altered dense dark greenish-black rock which occupies the central portions of some of these plugs, suggest that they have been derived from the same rock type as that represented in the Pine Ridge occurrence. For the most part, however, these plugs consist almost entirely of serpentine with some magnetite and locally notable amounts of chromite. This rock is pale green in color, granular locally, and nearly always intensely sheared at the margins of the plug. The peculiar blue-green color of the sheared serpentine has led the residents of the region to call it "blue rock." The plug on the crest of the ridge north of Danish Creek accounts for the name Blue Rock Ridge.

Where shearing has not been too intense thin sections show a relic texture of plates of antigorite strongly resembling the texture of the lherzolite of Pine Ridge.

On the south side of Long Ridge, in the Blue Rock fault zone near the western margin of the map, a small isolated patch of silica-carbon-

ate rock was found. The rock consists of red and brown chalcedony in a massive aggregate of carbonate crystals, usually tan in color and cut by stringers of white quartz. It was once mined for cinnabar.

The other serpentine masses are all small, usually a few tens of feet wide, and are apparently dikes since they are commonly elongate and cut across the regional schistosity. None of these could be followed for any distance.

Commonly the rock which comprises the dike is dark greenish-black in color, dense, and contains occasional light-green fibrous serpentine stringers, probably chrysotile. In thin section the rock is seen to be composed almost entirely of serpentine, which often shows the relic structure noted above. There is seldom much evidence of shearing, but locally sheared serpentine was found along the margins of the dikes. One of these dikes, that near the head of Bear Basin, was only mildly serpentinized and showed clearly the derivation from lherzolite. Hand specimens of all of the dike rocks are markedly similar in appearance.

Origin

It seems certain that the serpentine in this area has been formed by the alteration of lherzolite.

The mode of emplacement of these serpentine bodies presents an interesting and unsolved problem. No contact effects were seen in the surrounding country rock to suggest either extensive hydrothermal action after, or high temperatures during emplacement. In most of the plugs only the margins are intensely sheared, indicating that the differential movements may have been taken up largely along the boundaries of the serpentine bodies. In the San Clemente region the central portions of several of the plugs are severely fractured, but this fracturing may be related to movements along the fault which occurred long after the emplacement of the plugs. In the Pine Ridge plug the center is completely massive. The small dikes appear to have suffered little shearing during emplacement, although locally sheared margins were noted. The condition of these masses at the time of their emplacement, and the mechanism by which they were emplaced are not known.

Age

The age of the serpentine is not determinable in the Jamesburg quadrangle. It is definitely post-Santa Lucia, but no upper limit is available since the bodies are all found within the crystalline terrain.

To the west and south Trask (26, p. 140) and Reiche (37, p. 136) report serpentine derived from peridotite, and both refer it to the Franciscan. It seems likely that the serpentine in the Jamesburg quadrangle is of Jurassic age although in neither of the other areas has Jurassic serpentine been definitely reported in the basement complex. Reiche (37, p. 134), however, suggests that such masses may be present in the Lucia quadrangle.

Tertiary System

The Tertiary is represented by a thick series of sediments, the principal occurrence of which is in an almost continuous band trending northwestward just north of the center of the area. Isolated patches are scattered throughout the southern half of the quadrangle. With the exception of a small fault-sliver of Eocene sandstone, all the Tertiary

rocks are believed to be Miocene, although the age of some of the isolated southern units is still in doubt. Within the Miocene the Vaqueros-Temblor, Monterey, and San Pablo formations have been recognized.

Middle Eocene Sandstone

Three-quarters of a mile south of Uncle Sam Mountain there is a fault-sliver of Eocene sandstone an eighth of a mile wide and half a mile long, which has been dropped down into the basement rocks between two branches of the Church Creek fault.

The arkosic sandstone is medium-grained, well cemented with lime, dark gray to buff in color, and contains subangular to subrounded grains of quartz and feldspar. Biotite is sufficiently abundant to be clearly recognizable in hand specimens. Dark black carbonaceous flakes up to 8 millimeters in length are scattered through the sandstone. The intense shearing, small exposures, and massive nature of the unit, made accurate determination of the attitude impossible. Orientation of the biotite and carbonaceous fragments suggests a dip of about 30° NE. The sandstone has a minimum thickness of 250 feet.

A small fossiliferous horizon in the center of the NW¼ SW¼ sec. 25, T. 18 S., R. 2 E., M.D., about 500 yards southeast of the saddle, yielded abundant fossil material in which Dr. B. L. Clark identified the following:

Cardium lintium
Discocyclina clarki Cushman
Flabellum sp.
Ostrea cf. idriaensis
Phacopsis cf. raymondi
Puncturella sp.
Spiroglyphus cf. tejonensis (Arnold)
Venericardia sp.
Zenophora sp.

According to Clark the sandstone is of middle Eocene age and probably represents the upper Capay or Domengine horizon. Clark reports that Schenck has found the same horizon beneath the Vaqueros formation in the Reliz syncline.

Durham * studied the *Flabellum* and found it to be a new variety of the species *californicum* which he named var. *fiedleri* and referred to the middle Eocene.

The heavy-mineral study of the sandstone reveals a large percentage of biotite and a constant though small amount of pyrite as characteristic of the heavy suite.

Herold (36) has referred the Church and Miller Creek sandstones to the Eocene on the basis of foraminiferal studies by Laiming. No attempt was made to study the microfaunas, but megascopic materials from Miller Creek indicate that this sandstone is Miocene in age and it is so mapped in this work.

Miocene Series

The Miocene is represented in the Jamesburg quadrangle by a series of marine sediments more than 3,000 feet in thickness. This series has been divided, on the basis of lithology, into three units which have been mapped separately. The oldest and most widespread of these units is made up largely of sandstones and is Vaqueros-Temblor in age. The middle unit, comprised chiefly of fine organic and terrigenous shales is

* Oral communication. See J. Wyatt Durham, *Pacific Coast Cretaceous and Tertiary Corals:* Jour. Paleontology, vol. 17, no. 2, p. 196, pl. 32, fig. 18, March 1943.

correlated with the Monterey formation of surrounding areas. The upper sandstone unit is of San Pablo age.

The author wishes to emphasize that these units have been separated in the field on the basis of lithology and the contacts as shown on the accompanying geologic map may well cross time boundaries.

Vaqueros-Temblor Sandstone—Lower-Middle Miocene

Most widespread and varied of the Tertiary formations is the lower-middle Miocene arkosic sandstone. It includes minor amounts of siltstone and conglomerate; also, in one locality, an algal limestone, and in another a series of andesitic lavas.

Distribution

The largest continuous area occupied by the lower-middle Miocene sediments in the Jamesburg quadrangle is located along the north and east margins of the Tertiary belt which extends in a northwestward direction across the north-central part of the area. A continuation of this belt is located in the east-central part of the quadrangle and another occurs south of Tularcitos Ridge in the northwest rectangle. In these three locations the sandstone is associated with the younger Monterey formation.

Isolated patches of sandstone which have been mapped as lower-middle Miocene are scattered through the southern half of the quadrangle. The largest of these follows Pine and Church Creeks and extends southward into the Lucia quadrangle. Closely associated with this unit is the sandstone in Miller Canyon and its extensions both north and south on Hennickson's Ridge and at China Camp. The isolated patches at Bruce Ranch, Bear Trap Canyon, Hiding Creek, Redwood, and Ventana Creeks have also been included as Vaqueros-Temblor although the correlation of these units is uncertain. In all of these southern areas the sandstone occurs in association with crystalline rocks and in only one area have fossils been found.

Lithology

The most widespread and abundant lithologic type in the Vaqueros-Temblor formation is a coarsely bedded to massive, medium-grained, moderately cemented, arkosic sandstone, white or buff in color, moderately sorted, and comprised largely of almost equal amounts of quartz and feldspar. The grains are subangular but often, especially the coarser grains, subrounded. The feldspar is only moderately altered as a rule. Both orthoclase and andesine are usually present, the latter like that found in the basement rocks. Heavy minerals and argillaceous material are minor in amount.

Such is the dominant sedimentary type in the thin band southeast of Chupines Creek, at the east-central margin of the quadrangle, on the south side of Tularcitos Ridge, in Miller Canyon, Pine, and Church Creeks. In the Chupines Creek area the sandstone is finer grained, silty and poorly cemented, as is the Bruce Ranch occurrence. At Bear Trap Canyon, Hiding Creek, and north of Klondike Canyon, the sandstone is predominantly reddish brown, coarse, often pebbly and well cemented. Concretions are common throughout most of the sandstone of these areas. The concretions range from 6 inches to 6 feet in size, are usually ovoid or spherical in shape, and in many places are very abundant.

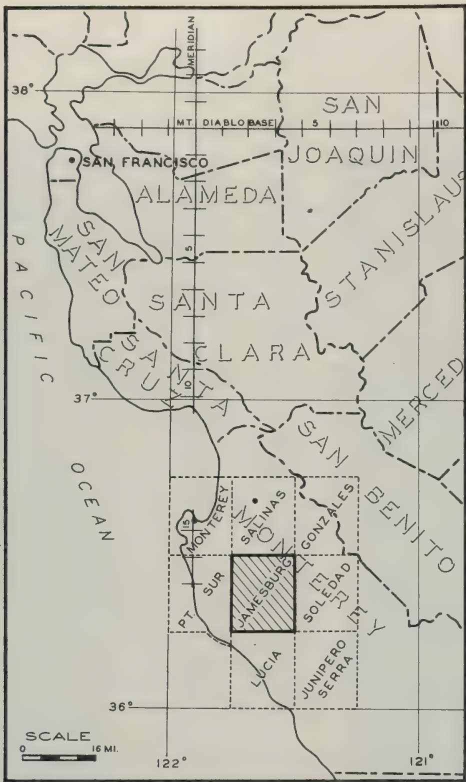


FIG. 1. Index map showing location of the Jamesburg quadrangle described in this report, and the position of adjoining quadrangles.

FIG. 2. View showing typical topography of the belt of Tertiary rocks which passes through the quadrangle, trending northwest. Tularcitos Ridge is in the right center background, Santa Lucia Range in the distance, Tularcitos Valley in the foreground.

FIG. 3. Panorama of typical topography of Santa Lucia Range. Looking northeast from Ventana Cone. Pine Valley, upper reaches of Carmel River, just right of center. Miller Creek beyond next divide, and Chews Ridge, on skyline. Note lack of uniformity of ridge crests. Sierra de Salinas in background to right. High point is 4348-foot peak above head of Pine Valley.

FIG. 4. Panorama from Ventana Cone. Looking north down Carmel River. High peak to right is Uncle Sam Mountain. Sierra de Salinas in background to right with Tularcitos Ridge immediately in front of it. Note marked differences in topography between Santa Lucia Range, Tularcitos Ridge, and Sierra de Salinas.

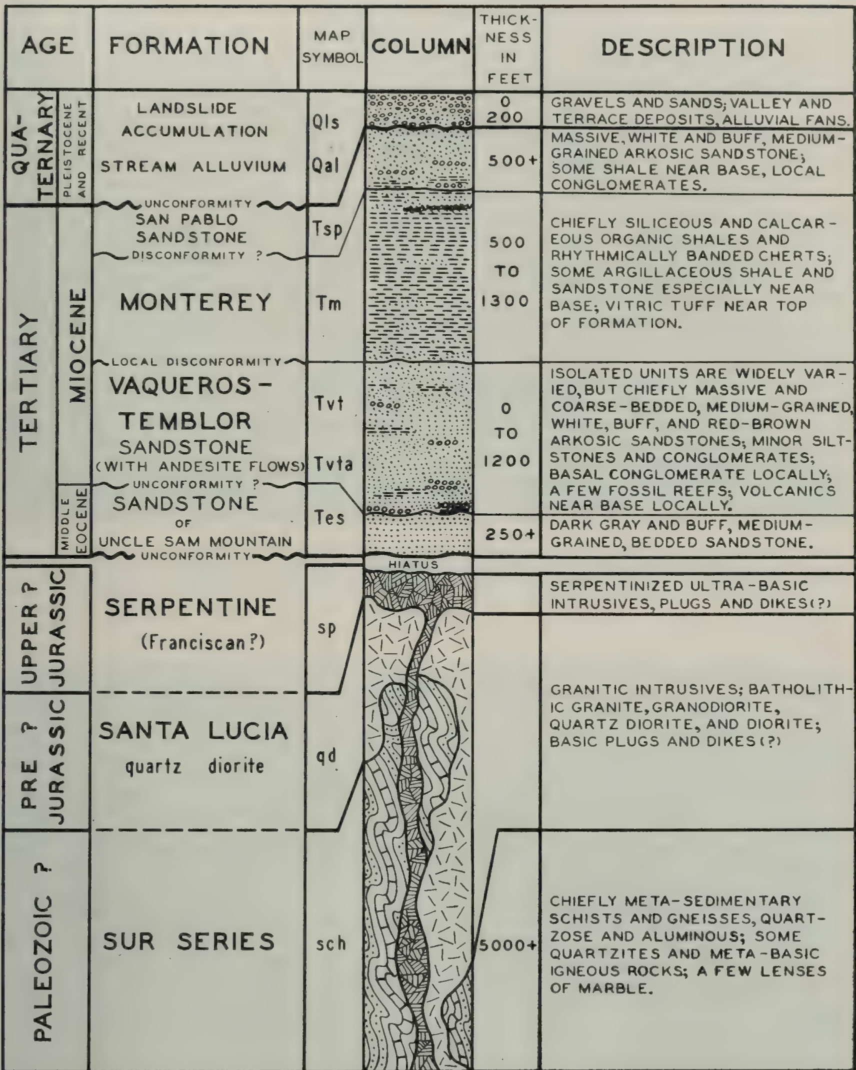


FIG. 5. Stratigraphic column of the Jamesburg quadrangle.

FIG. 6. Looking southeastward up Carmel Valley toward the northwest corner of the Jamesburg quadrangle, three miles distant. *Photo by Olaf P. Jenkins.*

FIG. 7. Looking down the Carmel River from a roadcut in granite, past Rancho Carmelo at Camp Stephani. *Photo by Olaf P. Jenkins.*

FIG. 8. Adobe plant of Carmel Building Specialities, located in the northwestern corner of the Jamesburg quadrangle, one mile southeast of Rancho del Monte, Çarmel Valley. Sun-dried adobe brick is made from top-soil of terrace deposit. *Photo by Olaf P. Jenkins.*

FIG. 9. Drinking fountain, Tassajara Hot Springs (see Waring 15). These springs are located in sec. 32, T. 19 S., R. 4 E., M.D., in the northeastern corner of the Lucia quadrangle 1½ miles from the border of the Jamesburg quadrangle. *Photo by Olaf P. Jenkins.*

FIG. 10. Looking north-northeast from a point near Jamesburg, toward Sierra de Salinas in the distance, and Tularcitos Ridge in the foreground.

FIG. 11. View of the upper end of Pine Valley, located in the upper reaches of the Carmel River. One of the few flat areas in the Santa Lucia Range in this quadrangle. Developed in Vaqueros-Temblor sandstone which outcrops above center to right. Looking northwest from deserted ranch.

FIG. 12. Looking due north toward Sierra de Salinas from the road near the summit of Tularcitos Ridge. *Photo by Olaf P. Jenkins.*

FIG. 13. Looking south from an old quarry in granite (for road material), located in sec. 23, T. 18 S., R. 4 E., M.D., east-central part of the Jamesburg quadrangle. *Photo by Olaf P. Jenkins.*

FIG. 14. View from Chews Ridge lookout station, Jamesburg quadrangle, northeastward across Paloma Creek, toward southern end of the Sierra de Salinas, which lies in the Soledad quadrangle. *Photo by Olaf P. Jenkins.*

FIG. 15. Looking southwest across the rugged mountains of the Santa Lucia Range from a point 2½ miles south of Chews Ridge lookout station. *Photo by Olaf P. Jenkins.*

FIG. 16. White marble intruded by pegmatite dikes. Located at Lime Point, near southern border of Jamesburg quadrangle, on road to Tassajara Hot Springs, 5.7 miles from Chews Ridge lookout station. Limestone from this deposit was used in the construction work at Tassajara Hot Springs. *Photo by Olaf P. Jenkins.*

FIG. 17. White pegmatite dikes intruding schist on road near border of Jamesburg and Lucia quadrangles. *Photo by Olaf P. Jenkins.*

FIG. 18. Pegmatite dike intruding schist in roadcut on south flank of Tularcitos Ridge. *Photo by Olaf P. Jenkins.*

FIG. 19. Vertically foliated schist on Tassajara Hot Springs road near the southern border of the Jamesburg quadrangle. *Photo by Olaf P. Jenkins.*

FIG. 20. Exposure of quartz diorite overlain by terrace gravels, located ¼ mile southeast of Camp Stephani. *Photo by Olaf P. Jenkins.*

FIG. 21. Well-bedded Vaqueros-Temblor sandstone near base of formation in Church Creek, near Caves. Basal depositional contact just beyond picture to right. Note weathered structures.

FIG. 22. Exposure of loosely consolidated sandstone along road on south flank of Tularcitos Ridge, near center of sec. 30, T. 17 S., R. 3 E., M.D. This massive bed of Vaqueros-Temblor sandstone forms dip-slope which the road follows for a third of a mile. *Photo by Olaf P. Jenkins.*

FIG. 23. Exposure of white Monterey shale containing a bed (P) one foot thick of brown pellet phosphorite (*collophane*) ; see Galliher 31. (The mineralogy of this deposit will be described in the forthcoming October *Journal.*) Located on Carmel River valley road one mile northwest of northwestern corner of Jamesburg quadrangle. *Photo by Olaf P. Jenkins.*

FIG. 24. Exposure of Monterey shale dipping 35° S. Located on Tularcitos Creek just west of Chupines Creek. *Photo by Olaf P. Jenkins.*

FIG. 25. Concretions of Vaqueros-Temblor sandstone showing spheroidal weathering. Located on southern side of Tularcitos Ridge.

FIG. 26. Vaqueros-Temblor volcanic agglomerate exposed on eastern side of ridge east of Madrona Canyon, elevation 2535 feet, near top of volcanic series.

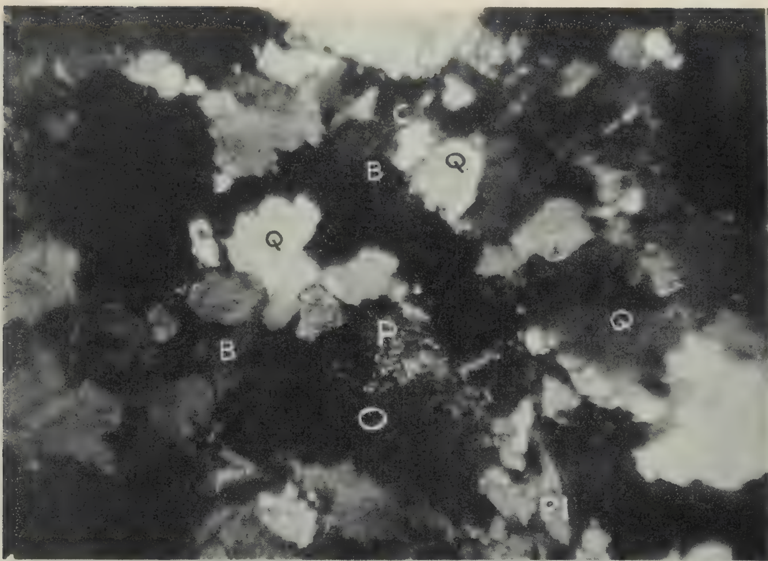


FIG. 27. Photomicrograph of quartz diorite showing strain effects. Note strain shadows in quartz (Q), bent and broken plagioclase (Pl) twins. A small area of perthite (P) near center. Orthoclase (O), biotite (B), and chlorite (C) present. Under crossed nicols. x 17.

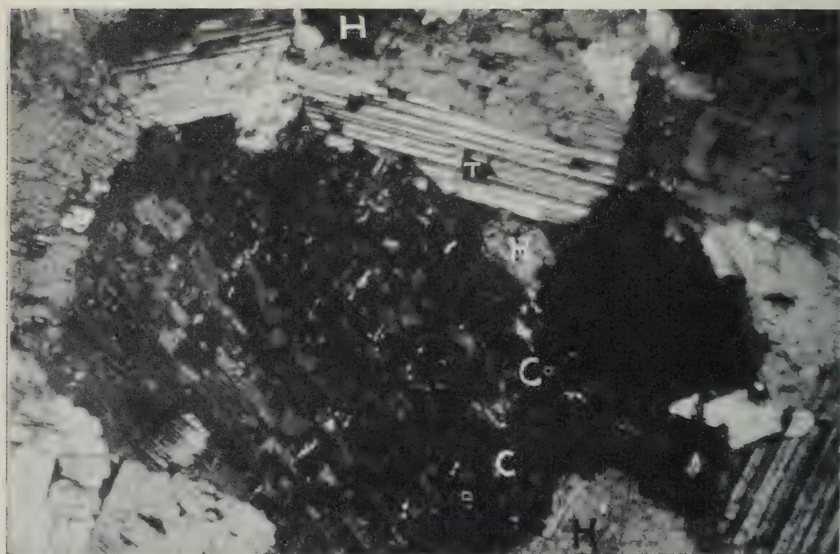


FIG. 28. Photomicrograph of diorite showing chess-board structure in plagioclase (andesine). Hornblende (H), chlorite (C), and titanite (T) present. Under crossed nicols. x 16.

FIG. 29. Photomicrograph of basic gabbro showing diopside (O) altering to pargasite (P). Note both amphibole and pyroxene cleavage patterns in large grain at center. Enstatite (E) altering to serpentine (S). Some labradorite plagioclase (Pl) present. Plane polarized light. x 65.

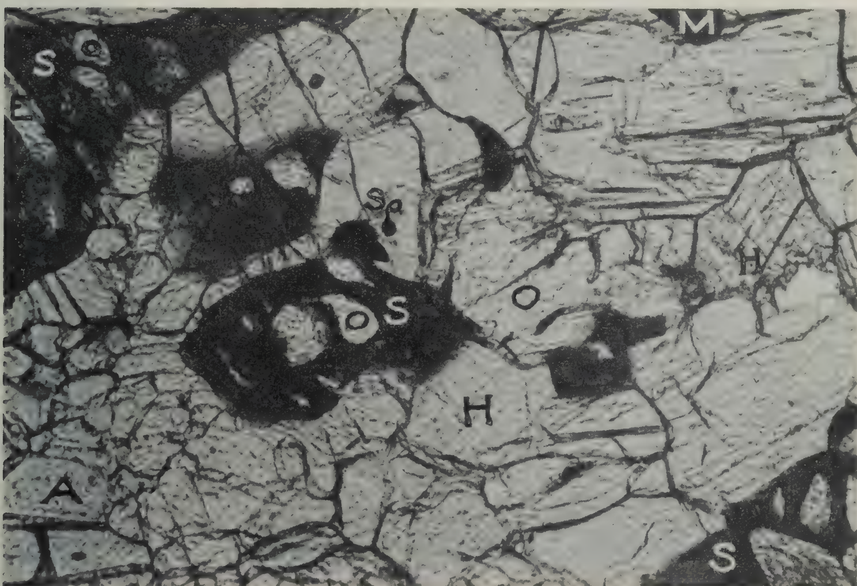


FIG. 30. Photomicrograph of lherzolite from center of Pine Ridge serpentine plug, showing olivine (O) and locally enstatite (E) altering to serpentine (S). Most of the grains are hornblende (H), but there is some augite (A). The percentage of hornblende is too high to be typical of this rock. A few grains of green spinel (Sp) and magnetite (M) are present. Plane polarized light. x 96.

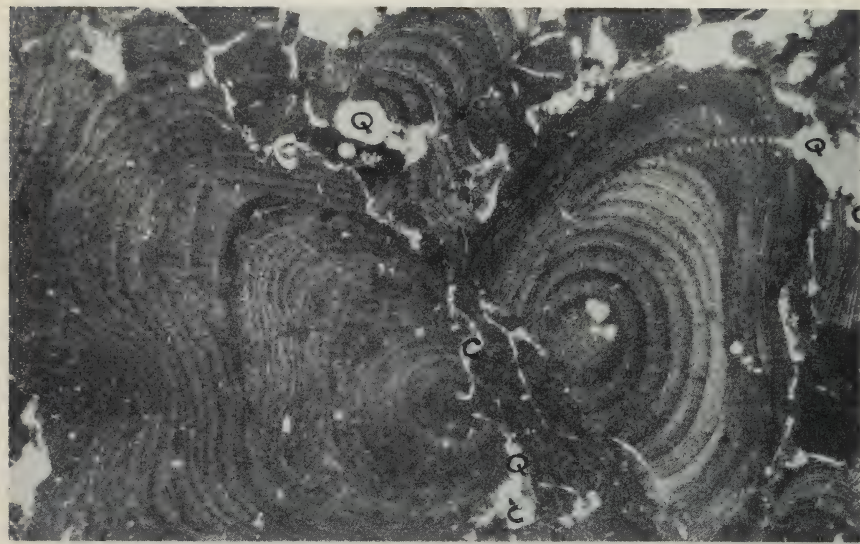


FIG. 31. Photomicrograph of algal limestone from Ventana Creek Vaqueros-Temblor (?). Grains of quartz (Q) and grains and stringers of calcite (C) between broken algal structures. Ordinary light. x 21.

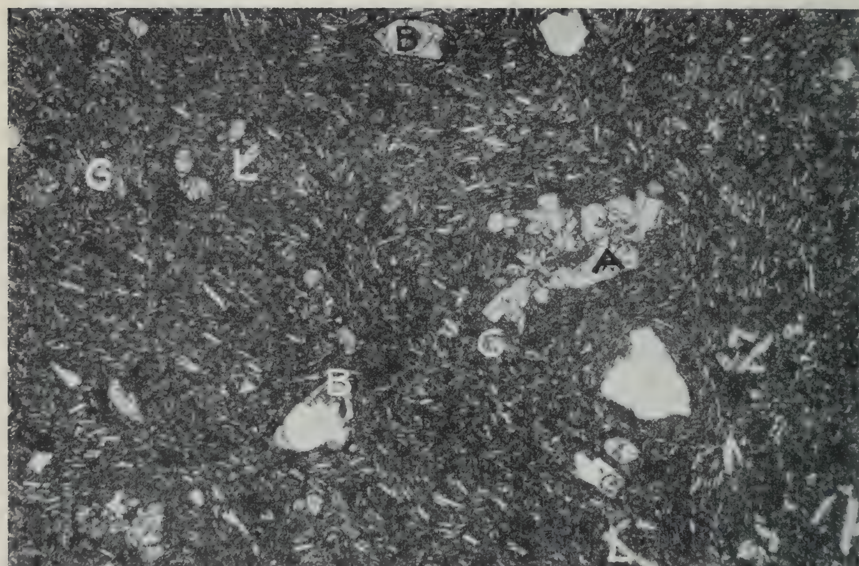


FIG. 32. Photomicrograph of olivine-augite andesite from Red Rock Hill east of Madrona Canyon. Bowlingite (B) pseudomorphs after olivine locally removed, leaving cavities (large white areas). Phenocrysts of augite (A) and labradorite (L). Sizeable areas of clear brown glass (G). Groundmass hyalopilitic with felted andesine feldspar laths in dusty glass spotted with red iron oxide. Ordinary light. x 22.

In the northwestern Tularcitos area and in the Cachagua area the lower part of the formation is coarse, red-brown or buff well-cemented sandstone, whereas the upper parts are finer, white, and poorly consolidated. To the east the white unconsolidated sands lie directly on the basement rocks, while in many of the isolated southern units they are absent.

Basal conglomerates are exposed beneath the sandstone in several localities as, for example, at Hiding Creek, on Tularcitos Ridge, and in Church Creek. Pebbly sandstones are widespread. Locally, conglomerates occur within the sandstone unit, as at Redwood Creek and north of Klondike Canyon. In all of the coarse clastics the pebbles and boulders are chiefly quartz diorite, pegmatite, quartzite, and gneiss obviously derived from the Santa Lucia and Sur series. Locally volcanic porphyry pebbles occur. In most localities the pebbles are well rounded and range from 2 to 6 inches in size, but locally boulders up to 6 feet in diameter have been found. As a rule the conglomerates are not well consolidated, but locally, especially where they are exposed in the creek bottoms, they are extremely well cemented. In the Church Creek occurrence the basal conglomerate exposed in the bed of the creek is extremely well cemented while that just above the creek is unconsolidated.

Locally siltstones are found within the sandstone units. Red, green, and gray shales are abundantly developed in the China Camp and Church Creek areas and minor argillaceous beds, usually gray or brown in color, are present throughout the entire area.

In the Ventana Creek area, the sandstone, doubtfully correlated with the Vaqueros-Temblor, is underlain by a cherty algal limestone. No suggestion of algal structure can be seen in hand specimens of this dense gray-brown calcareous rock, which appears to be comprised of a series of small (average 2 millimeters) extremely fine-grained cherty-looking blocks so nicely fitted together into a mosaic pattern that there is little interstitial material. Occasionally a crystal of quartz, calcite, or biotite is noted and locally the rock is cut by an intricate pattern of tiny white quartz stringers which stand out as ridges on the light-gray weathered surface. Small areas of white or tan medium-grained crystalline calcite interrupt the blocky mosaic.

In thin section the algal structure is beautifully displayed. Calcite stringers, quartz, and biotite grains are present. The algae are probably a species of *Lithophyllum,* according to Professor William A. Setchell.*

Andesitic Volcanics. In the vicinity of Madrona Canyon the Vaqueros-Temblor sandstone lies depositionally upon, and apparently in part beneath a series of andesitic flows and breccias which have an estimated maximum thickness of 250 feet.

The best exposures are on the crest of the ridge north of Madrona Canyon on Red Rock Hill. South of the canyon exposures are less plentiful, but sufficient for fairly accurate mapping. An eighth of a mile northwest of the center of sec. 9, T. 18 S., R. 4 E., M.D., another small patch of lava covers the crest of the ridge.

* Oral communication.

The most common lava is a black, dense, sparsely porphyritic andesite in which weathering of olivine phenocrysts has produced a vesicular-like texture. The dense red lava, from which Red Rock Hill takes its name, is limited to the crest of that hill. Although megascopically the lavas appear to be varied, they are remarkably similar when studied in thin section. They show phenocrysts of augite, labradorite, and bowlingite pseudomorphs after olivine in a hyalopilitic groundmass composed of fine felted andesine laths and a dusty glass specked with grains of iron oxide. The glass is intermediate in composition and the rock is classified as a basic andesite. One of the most interesting microscopic features of these rocks is a clear light-brown glass which occurs both as irregular slivers in the groundmass and also as rather large continuous blocks. Apparently this represents an earlier chilled phase which was later broken and forced down into the flows.

Near the top of the lava medium-coarse fragmental material outcrops. Exposures are rare on the ridge east of Madrona Canyon where the unit consists of scattered bombs up to 2 inches in size in a fine matrix of ash. Much of the coarse material is angular and not larger than 2 centimeters in size. The entire mass has been thoroughly solfatarized, and large amounts of opal have been developed. The rock is crumbly and pale yellow-brown in color. It is spotted with blue-black and dark red fragments.

On the southeast side of the ridge east of Madrona Canyon at an elevation of 2325 feet just below the ridge crest there outcrops a nearly vertical wall 12 feet high made up entirely of small (average 3 inches) red-brown, highly vesicular bombs with no matrix material between the fragments. The source of this agglomerate must have been nearby.

Nowhere is the contact between the sandstone and lava exposed, but the field relations indicate that, for the most part, the sandstone lies depositionally upon the igneous rocks. No contact effects are to be seen in the sandstone. To the east the relationships are more complex. A long tongue of sandstone, well exposed, and lying depositionally on the granite, extends, apparently, under the lava. Elsewhere the lava seems to have filled a deep valley in the pre-Miocene surface, and, except for this tongue of sandstone, the lava might well be pre-Vaqueros in age. The apparent position of the lava above the sandstone to the east indicates that it is contemporaneous with the sandstone.

The isolated lava patch to the southwest apparently lies on the Santa Lucia basement rocks although lack of outcrops in this area makes the determination uncertain.

Similar andesitic lavas are reported by Trask (26, p. 145) from the Point Sur quadrangle where they lie near the top of the Temblor sandstone and are interbedded with it. His mapping of this flow shows that the relation of the lava to the sandstone is not a simple one. He too finds isolated patches of lava on the crystalline rocks and concludes

> "* * * it suggests that the lava flowed over the limits of the Temblor onto the quartz diorite."

Thickness

The Vaqueros-Temblor sandstone attains a maximum thickness of 1200 feet near the southern end of the Tularcitos syncline. Both to the northwest and southeast it thins to about 500 feet. The Cachagua Creek, Miller, and Church Creek occurrences have a maximum thickness comparable to the Tularcitos, but most of the small isolated sandstone areas

to the south contain less than 500 feet of sediment. In the Hiding Creek occurrence the thickness is less than 100 feet.

In the main sedimentary area there are notable variations in thickness along the strike, but more marked is the thinning of the formation to the south where the Monterey shales overlap the older sandstones and lie directly on the basement rocks. The absence of the sandstone beneath the Monterey shales on the crest of Tularcitos Ridge, together with the presence of thick masses of sandstone to the northeast and southwest, suggest that this area may have been an island in the Vaqueros-Temblor sea. The presence of conglomerates in the sandstones on the south side of Tularcitos Ridge lends some support to this theory.

Relation to Adjacent Formations

At numerous localities the Vaqueros-Temblor sandstone lies depositionally on the pre-Jurassic Santa Lucia and Sur rocks. Nowhere is the contact so well exposed as in Carmel Valley near Hiding Creek. Here in the steep cliff which marks the western side of the canyon the contact is exposed for a quarter of a mile. A basal conglomerate of well-rounded pebbles and boulders, largely Sur and Santa Lucia material, lies upon the Sur schists and gneisses. The sea floor was relatively flat although locally there were gentle undulations. The conglomerates grade upward into the medium-grained red-brown sandstones which make up the bulk of the sedimentary unit in this area.

The basal contact of the small nose of sandstone which extends into the northwest corner of the area from the Salinas quadrangle is notably different. The basal unit of the sandstone is conglomeratic, but it is composed very largely of fine granitic debris, and contains abundant fossil fragments. The granodiorite upon which the conglomerate rests is weathered to a depth of at least 5 feet and were it not for the fossil fragments it would be impossible to tell where the older rock stops and the sediment begins. Pebbles in the conglomerate range up to 6 inches in size and are themselves deeply decomposed. The depositional surface here has a relief of at least 15 feet.

At the head of the little gully an eighth of a mile east of the fault near the crest of Buckeye Ridge the basal sandstone contact is again exposed. Here too the older rocks were weathered before deposition of the sandstone and much granitic material is found mixed with the basal sandstone which, however, is not conglomeratic in this locality.

On the north side of Chupines Creek and locally on Tularcitos Ridge, there is a basal conglomerate between the sandstone and the basement complex. Elsewhere in the area the lower contact is not well exposed although in many places sandstone and crystalline rocks are found in place within a few feet of one another with no suggestion of a basal conglomerate.

The trace of the basal contact suggests a gently undulating surface in most localities, but the sea floor was marked by major irregularities as well. As previously noted the Tularcitos Ridge area may well have been an island in the Vaqueros-Temblor seas and the area between lower Chupines and Klondike Canyons may have been another such island. Variations in lithology between units suggest that the sediments may have been deposited in more or less isolated troughs.

The sandstone is overlain disconformably by the overlapping Monterey formation. The actual contact between the two formations is

exposed in only one locality, namely on the south end of the ridge west of Trampa Canyon. Here the sandstone surface upon which the shale was deposited has a relief of as much as 50 feet. There is a suggestion of a mild angular discordance between the two formations. The shales have a dip of 15° to 20°, and the sandstones are believed to dip at an angle of 25° to 30°. Because of the massive character of the sandstone in Trampa Canyon it was impossible to obtain a definite determination of the attitude. In most of the area a depositional surface of low relief is suggested by the mapping, and conformable relations seem to prevail, although the difficulty of obtaining satisfactory attitudes in the massive sandstone makes it impossible to preclude a slight angular discordance. This discordance may be explained by the transgression of the later sea.

In the east-central area there seems to be a lithologic gradation between the two formations and continuous deposition throughout the lower and middle Miocene. However, even in this area the Monterey overlaps the older sandstone and lies directly on the pre-Tertiary basement rocks. Similar overlap occurs to the northeast on the east end of Tularcitos Ridge, in the vicinity of Jamesburg, and between Klondike and Chupines Creeks. Throughout most of the area, then, at least a disconformity separates the two formations.

Conditions of Deposition

Evidence has been cited above leading to the conclusion that the Vaqueros-Temblor may have been deposited in a series of troughs locally broken by islands. Weathering of the basement rocks before deposition of the Miocene sands is clearly indicated. The abundance of relatively fresh feldspar in the sands suggests a semi-arid climate. That the materials were of local derivation seems assured by study of the heavy minerals, by the nature of the conglomerate pebbles and boulders, and by the composition of the feldspars in the sands.

To the southwest some of the occurrences, notably that at Redwood Creek, may be of continental origin. Lack of fossils, lenticular bedding, and the rapid lithologic variation support, but do not prove this contention. To the southeast and northwest Trask (26, p. 148) and Schombel (40, p. 16) report continental Temblor deposits.

Fauna and Age

Though some of the fossil material is well preserved much of it is in such poor condition as to make accurate determinations impossible. Professor B. L. Clark made both the determination and interpretation of the collections. Many of the forms, indeed the most abundant types, are believed to be new species, and merit further study. The collections place the unit within the Vaqueros-Temblor transition zone, possibly extending well into the Temblor, but not including any of the lower Vaqueros.

Herold (35, p. 31) lists 19 species from the Jamesburg quadrangle, among which the presence of the typical Temblor *Turritella ocoyana* Conrad is especially noteworthy. His species determinations of both *Anadara* and *Venerupis* are, however, doubtful. There may be several new species represented.

The collections from Miller Canyon are of especial interest since the unit there was determined as Eo-Oligocene by Herold (36) as a result of foraminiferal studies by Laiming. The megascopic fossils clearly place this unit in the Miocene Vaqueros-Temblor transition zone.

Herold's (35, p. 55) determination of *Anadara* (*Arca*) *obispoana* (Conrad) is not valid, according to B. L. Clark, the *Anadara* being a new species. This erroneous determination led Herold to separate a Monterey sandstone unit from the lithologically and structurally similar Temblor sandstone in the Salinas quadrangle. No evidence, either lithologic or structural, was seen in the field to support this division, and in the Jamesburg quadrangle the entire sandstone unit has been mapped as Vaqueros-Temblor.

The algae found in the limestone of Ventana Creek are, according to Professor William A. Setchell * a branching type of crustaceous red algae, probably a species of *Lithophyllum.* This genus is not believed to have appeared prior to the middle Tertiary.

V. L. Vander Hoof studied a vertebrate collected some years ago from the sandstone of the Cachagua area. In a personal communication to the author he reports:

> "In July, 1931, the Museum of Paleontology of the University of California collected the lower jaw of a marine mammal from the NE¼ SE¼ sec. 30, T. 17 S., R. 3 E., elevation 1400 feet U.S.G.S., Jamesburg quadrangle.
>
> "The animal represented belongs to the mammalian order Sirenia and is apparently distinct from either of the two recognized sub-orders (Desmostyliformes and Trichechiformes). Hence it is of no great value as a horizon marker. If, however, the specimen should be desmiostylid, its relationships would seem to indicate a form more advanced than *Cornwallius,* the Oligocene genus, but considerably less advanced than *Desmostylus,* the Temblor and Briones genus. The true systematic position of this sirenian from the Jamesburg area cannot be adequately determined until more complete material is discovered. When this is done, we may be able to say more about its stage of evolution and thus its position in time."

Heavy Minerals

A study of the heavy minerals of the Vaqueros-Temblor sandstones was undertaken to provide evidence for or against the correlation of the isolated sandstone areas of the south with the northern fossiliferous units.

Unfortunately the first test-runs showed some promise and led to a rather extensive study, which, as will be seen, gave few if any positive results. The first few samples from the Tularcitos area seemed to establish the persistence of the heavy suite within a given area. Samples from the Eocene sandstone next studied, while similar in themselves, were markedly different from the first group. A sample from Miller Creek proved similar to one from Tularcitos, and encouraged further work.

Since the top of the sandstone has been removed by erosion in many places it seemed best to take samples from near the base and wherever possible an effort was made to select samples of about the same lithological character, as close to the typical medium arkosic sandstone as possible. The samples were crushed and screened, and the heavy minerals separated from two fractions of each sample—the .250-millimeter and .125-millimeter fractions. The heavy separates were then mounted in balsam for study. After determination of the mineral types the relative percentages were recorded.

Not until a large number of samples had been tested did the wide variability within the Vaqueros-Temblor sands become apparent. Further work demonstrated that samples from areas close together and almost certainly continuous showed variations as great as samples from widely separated areas.

---

* Oral communication.

Since the total percentage of heavy minerals varies within the sediments, an attempt was made to correlate this difference with the variation in suite, but without any success. Nor is grain size of any help in explaining the discrepancy. In general the finer sediments have fewer heavy minerals, but the character of the heavy suite seems to show no relation to either grain size or total heavy percentage.

In a very general way it seems possible to separate the Eocene and San Pablo sands from those here mapped as Vaqueros-Temblor. In both of the former the heavy suites are notably similar in all samples studied and show small but consistent differences from the Vaqueros-Temblor suites. The Eocene sand is characterized by abundant biotite and relatively sparse but persistent pyrite. The San Pablo is less distinct, but the lack of any one predominant mineral and the persistent presence of notable and almost equal amounts of biotite, garnet, epidote, magnetite, and leucoxene is quite characteristic.

Within the Vaqueros-Temblor sandstones there is wide variability, not only from area to area, but within single occurrences as well. Samples from the Church-Pine Creek and east-central areas, for example, show as much variation between individual members as do samples from widely separated regions. There is a suggestion of uniformity in some of the occurrences, as for example the Tularcitos (which is much like the San Pablo), Cachagua (not unlike the Eocene sandstone), and Miller Creek. On the whole, however, no definite characteristics could be established. Biotite is always present and though garnet, zircon, epidote, and magnetite are almost always represented in substantial amounts they vary widely in relative proportions and one or more of these minerals are completely lacking in some of the samples. In some biotite predominates, in some garnet, in others epidote. Nor does there seem to be any mineral which though small in amount is persistent and unique in all of these sands. Lack of any characteristic heavy suite or varietal mineral might be taken as an indication that the correlation of the widespread and isolated sandstone units is not valid, but since the same deficiency is found between units of known age-equivalence and within lithologically and structurally continuous units as well, the discrepancy carries little weight even in this negative way.

Although of no aid in correlation, either positive or negative, a comparison of the heavy minerals with analyses of the basement rocks of the area indicates that most of the heavies could have been derived from the local basement rocks, and lends support to the theory of local origin of the sediments.

Discussion of Individual Vaqueros-Temblor Occurrences

Tularcitos Area. The Vaqueros-Temblor sandstone in this area occupies a narrow belt an eighth to three-quarters of a mile wide extending for 9 miles along the northeast margin of the Tertiary zone from the divide southwest of Madrona Canyon northwest to Buckeye Ridge. At either end it is cut off by cross-faults. North and west of Buckeye Ridge the sandstone area widens to occupy most of the region north of Chupines Creek and extends beyond the limits of the map area into the Salinas quadrangle to the north. In the northwest corner of the map the sandstone folds around the nose of the syncline whose center is here occupied by the Monterey formation. To the west the sandstone has anticlinal structure. Throughout the narrow belt south

of Buckeye Ridge the formation strikes N. 30-50° W. and dips 30° to 60° SW. The massive, medium to coarse, white, poorly cemented and well-sorted arkosic sandstones range from 1200 to 500 feet in thickness along the east side of the syncline, attaining a maximum thickness near Corral Viejo Creek. Between lower Chupines and Klondike Canyons the unit thins out and completely disappears beneath the overlapping Monterey shales. North of Buckeye Ridge the sandstone is markedly different; better stratified, not so well sorted, and more varied in lithologic character. A section in the southern part of this area, taken in the valley ⅝-mile west of the 1942 hill on the west end of Buckeye Ridge, is given below:

	Thickness in feet
Top	
Finely bedded poorly cemented argillaceous white sandstone with a few thin white limey shale beds near top	60
Fossiliferous brown well-cemented medium-grained arkosic sandstone with minor gray shale interbeds 1 to 5 feet in thickness and fossil reef near top	25
Massive medium-grained poorly cemented white arkosic sandstone	125
Buff medium-grained moderately cemented arkose with beds from 2 to 6 feet thick	35
Brown medium-grained well-cemented calcareous sandstone with abundant broken fossil fragments	3
Massive to coarsely bedded, red-brown to tan, medium-grained arkosic sandstone with occasional small conglomerate and pebbly sandstone lenses	110
Base (not exposed)	
Total	358

This section was taken near the top of the formation.

The sandstone in the area north of Chupines Creek is chiefly a fine argillaceous variety. North of Klondike Canyon the sandstone is coarse-grained, brown in color, and contains many conglomerate lenses with pebbles chiefly of quartzite and granitic rocks which average 2½, but occasionally reach 6 inches in size. In this region there is very rapid lithologic variation within the sandstone, both vertically and horizontally. Abundant though usually poorly preserved fossil remains and occasional fossil reefs attest to the marine origin of the formation. Shallow marine conditions seem to be indicated.

Higher in the section to the west, the fine, white, more uniform sandstone outcrops in Klondike and adjacent canyons.

The basal contact of the sandstone is exposed only in the two localities already described. Apparently the sandstone was deposited on a weathered surface of low relief. The Del Monte fault along the northern margin of the map brings the basement rocks up against the sediment. Near Madrona Creek the sandstones lie on and apparently, in part at least, under the olivine andesite flows which seem to have filled a valley in the old erosion surface.

Nowhere throughout this entire area is the upper contact between the sandstone and Monterey shale exposed, and the mapping has been done largely on the basis of float.

Herold (35) subdivided the formation in the Salinas quadrangle into two separate units, the Temblor and Monterey, but despite careful checking in the Jamesburg area, no evidence, lithologic, structural, or paleontologic, could be found to support this determination; and the entire sandstone has been mapped as a unit.

Cachagua Area. On the south side of Tularcitos Ridge is another sandstone known to be of Vaqueros-Temblor age. It is poorly exposed, and its lithology, apparently consistent in general characteristics, varies rapidly in detail. The sediment is chiefly a medium- to coarse-grained, well-cemented and well-sorted brown to reddish-brown arkosic sandstone. Pebbly sandstones and fine conglomerates are common in the lower parts of the formation and concretions ranging from a few inches to 6 feet in diameter are abundant. The upper portion of the formation is a white, poorly cemented and well-sorted arkose. The fault sliver on Long Ridge is of this same type.

The sandstone is predominantly massive and attitudes are not easy to obtain, but available evidence points to a rather uniform strike of N. 40-45° W. and a dip 20-30° SW. The dip decreases to the southwest and is nearly horizontal in the neighborhood of Carmel River. Beneath the terrace gravels of the Carmel on the nose of Blue Rock Ridge the standstone dips to the northwest where it has been dragged up along the Cachagua fault. Although the sandstone attains a maximum thickness of 1200 feet it thins out completely beneath the Monterey shales in the Trampa Canyon area.

To the east, the sandstone lies depositionally on the quartz diorite, although the contact itself is nowhere exposed. To the northwest the sediment is cut off by two faults, and just west of Trampa Canyon a cross-fault has displaced the basal contact a mile to the southwest.

Monterey shale overlies the sandstone, the contact exposed on the ridge front west of Trampa Canyon having already been described. Within this area there seems to be evidence of a marked disconformity, if not an angular unconformity, between the two Miocene units. Several small isolated patches of Monterey mark the axes of synclines within this area.

East-Central Area. The sandstone in the east-central area is markedly similar to that of the southern Tularcitos area. It consists predominantly of massive, medium- to coarse-grained, well-sorted, poorly cemented white arkose. To the north it has a minimum thickness of 500 feet, but it thins out to the southeast. The upper portion of this unit is somewhat finer grained argillaceous, and contains numerous interbeds of shale. Since the overlying Monterey formation contains clastic shales and sandstones at its base, the two formations grade into one another lithologically. Deep gullies abound in this area and outcrops are abundant, but it was difficult to separate the two formations. The contact has been drawn at the top of the highest large sandstone unit.

The sandstone appears to lie depositionally on the older crystalline rocks to the northwest and west, but to the northeast the Santa Lucia quartz diorite has been faulted up against the sediments, locally dragging the sandstones to a steep southwest dip. Attitudes are almost impossible to find in the northeastern portion of the area, but they are probably of low dip and northwest strike, and continue the minor folds mapped in the Monterey formation to the southeast.

Miller Creek Area. Massive or coarsely bedded, medium-grained, brown or buff, arkosic sandstones which are moderately well cemented make up most of the Vaqueros-Temblor in this area. The sediments

strike N.40-45°W., dip 30-40°NE., and attain a maximum thickness of about 1100 feet. Interbedded with the sandstones are numerous fine blocky red, green, and gray shales and locally conglomerate beds. The shale beds are apparently lenticular, occur chiefly in the southern end of the area, and are abundant in the isolated fault sliver near China Camp. Conglomerates occur at two or more horizons. A basal conglomerate containing boulders up to 2 feet in diameter is exposed in the canyon in the NW$\frac{1}{4}$ sec. 1, T. 19 S., R. 3 E., M.D. The coarse materials are composed largely of Santa Lucia intrusives and there are occasional porphyry lava pebbles. Farther north in sec. 36, T. 18 S., R. 3 E., M.D., pebbly sandstone and fine conglomerate with many fossiliferous sandstone boulders were noted high in the section. The boulders in this conglomerate are so similar to the surrounding sandstones that an intra-formational origin is indicated. The red-brown sandstone sliver north of the main Miller Creek occurrence is pebbly throughout and contains some fine conglomerate lenses as well as fossil reefs. Still farther to the north on the southeastern end of Hennicksons Ridge the sediment is chiefly a white arkose, but contains some red-brown sandstones and conglomerate lenses.

Fossil reefs occur sparingly in the upper part of the section, but the material is usually so broken up as to be of little determinative value. Concretions, usually buff in color and ranging up to 2 feet in diameter, are fairly common all through the sandstone.

The main Miller Creek sandstone mass lies depositionally on the older Sur rocks to the southwest, although the actual contact is nowhere exposed. Several small areas of crystalline rocks, completely surrounded by the sediments, were found in the creek bottom in the NW$\frac{1}{4}$ sec. 1, T. 19 S., R. 3 E., M. D., and attest to the uneven character of the depositional surface. Mapping in this particular region is complicated by inaccuracies in the topographic map.

Intense shearing in the Sur rocks along the margin of the sandstone attests to the faulted nature of the contact northeast of the main mass and on either side of the isolated slivers to the north and south.

The designation of this sedimentary unit as Vaqueros-Temblor is based on the identification of material collected in the fossil reef near the top of the formation. The marked similarity in lithology with the northern sandstones supports the correlation. This sandstone unit has been assigned to the Eocene by Herold (36) on the basis of Foraminifera.

Pine and Church Creek Area. The predominate member of the Vaqueros-Temblor unit in this area is a medium-grained, massive or thick-bedded, buff, moderately cemented, arkosic sandstone. In addition, both shale and conglomerate lenses are present. The formation has a maximum exposed thickness of 1000 feet and a fairly persistent attitude, striking N.40-45°W. and dipping 30-35°NE.

In general, the lower horizons are somewhat coarser grained than the upper, and shales occur chiefly in the upper parts of the formation in the Church Creek area. The shale beds are lenticular and composed of fine red and green silt. Locally the shales are mud-cracked and everywhere they are blocky and concretionary. Small lenticular beds of conglomerate occur near the base of the formation and a basal conglomerate is exposed where the lower depositional contact crosses Church

Creek. The conglomerate pebbles, up to 6 inches in diameter, consist principally of quartz diorite and gneiss with minor quartzites and a few red and black porphyry pebbles.

Concretions are common and the sandstone weathers to form bowl-shaped depressions and caves, some of which, in the southern part of sec. 13, T. 19 S., R. 3 E., were formerly occupied by Indians who decorated the walls with crude pictures. Huge boulders some 30 feet or more in diameter fill the lower parts of the valley of Church Creek. Outcrops are continuous along most of the southwest margin and large barren slopes have been developed on the dip slope of the sandstone.

To the southwest the sandstone rests depositionally on the older pre-Jurassic rocks. Although the actual contact was not observed, the trend of the contact suggests a surface of moderate relief.

Sur metamorphics have been thrust over the sandstone from the northeast. The sandstone shows little shearing, but local southwest dips indicate drag effects.

No fossils were found in this area. The lenticular bedding and local mud-cracking in the shale suggest shallow-water or continental origin. The sandstone continues to the south into the Lucia quadrangle where it was mapped by Reiche (37, p. 144) as Eo-Oligocene, the age determination being based on the foraminiferal study of sands from the Jamesburg quadrangle by Herold (36). No attempt has been made to check this determination, but because of the striking lithologic similarity to the adjacent Miller Creek sandstone (also Eo-Oligocene according to Herold) in which Vaqueros-Temblor megafossils have been found, the sandstone has here been included in the lower-middle Miocene group.

Bruce Ranch Area. Underlying the flat region surrounding Bruce Ranch is a fine- to medium-grained, white to buff, silty sandstone with a maximum exposed thickness of 200 feet. Lithologically the sandstone is similar to that north of Chupines Creek. The only exposures are in road cuts and in small gullies east of the ridge where the sandstone seems to rest depositionally on the older rocks and dips gently to the southwest. Along the southwest and northeast margins intensely sheared Sur gneiss indicates fault contacts.

The isolated patch of sandstone south of Bruce Ranch is identical lithologically with the northern occurrence and seems to have about the same attitude. It is definitely separated from the northern mass by a narrow band of Sur metamorphics. Its relation to the adjacent rocks is not known, but the southwest contact is believed to be faulted.

Lacking any evidence to the contrary, this sandstone has been included with the Vaqueros-Temblor.

Bear Trap Canyon. At the head of Bear Trap Canyon (the eastern branch of Anastasia Creek) an orange or red, coarse, porous, well-sorted sandstone outcrops on the side of 3834 hill. The sandstone dips 26° SW., strikes N.40° W., and has an exposed thickness of 150 feet. The northeastern and eastern contacts appear to be depositional. Sheared Sur schists, a series of aligned springs, and an isolated sandstone sliver in the creek bottom suggest a fault bounding the southwest margin of the sediment.

This unit has been included doubtfully in the Vaqueros-Temblor.

Carmel River Occurrences. Nowhere in the area is there a sedimentary unit so well exposed as the sandstone of Carmel Canyon near the mouth of Hiding Creek. The flat lower ridge crests west of the river are developed on the dip slope of the sediments whose maximum thickness in this area is only about 90 feet. A coarse orange arkosic sandstone, much like the unit in Bear Trap Canyon, is characteristic of this area, but to the east in sec. 32, T. 18 S., R. 3 E., in the middle of Hiding Creek, a white to buff, medium to coarse arkose, more like the sandstone of Pine Valley, predominates. As the base of this eastern deposit is not exposed these sediments may represent the higher phase of the thin sandstones exposed in Carmel Valley. In the eastern area the sandstones reach a thickness of 350 feet.

In the Carmel Valley area proper, in addition to the red-brown arkose mentioned above, there are local green shales, and at the base a coarse conglomerate. A partial section measured in the northern and largest of these sandstone patches follows:

	Thickness in feet
Top	
Coarse, well-cemented, moderately sorted, red arkosic sandstone in beds 5 to 10 feet thick	27
Fine argillaceous brown sandstone with alternating layers of gray-green siltstone 6 to 8 inches thick	12
Green fissile shale	6
Sandstone grading from fine shaly sandstone above to coarse pebbly sandstone below. Finely bedded with 1- to 2-inch beds of alternate white and tan layers	14
Extremely coarse basal conglomerate with boulders of granitic material, pegmatite, and some quartzose gneiss in a brown coarse arkosic matrix. Average size of boulders 2 feet; maximum, 6 feet	13
Base (Sur gneiss)	
Total	72

The coarse basal conglomerate is well exposed along the banks of the river. Outcropping at the water's edge to the north, it rises 100 feet above the stream level, then returns to the stream at the mouth of Hiding Creek. It varies considerably both in thickness and lithology along its strike. To the south the conglomerate is thinner and has few boulders more than 3 feet in diameter.

In this locality the sandstone is only a thin veneer across the older rocks on the lower ridge slopes and even the small tributary streams have cut through it and into the crystalline rocks below, separating the occurrence into three distinct and isolated patches.

The sediments have been folded into broad open folds which trend slightly north of east and pitch eastward. Cutting a deep channel across the axes of two of these folds, the Carmel River has exposed a cross section of folded sedimentary rocks on a metamorphic basement. The larger tributary streams have similarly produced longitudinal sections across the folds. Huge blocks of sandstone litter the Carmel Valley for many miles in and below the sedimentary area.

Intense shearing in the schists and abrupt truncation of the folds indicate a fault along the eastern margin of the northern Carmel unit and of the unit to the east in Hiding Creek. All other contacts are depositional, the surface being fresh and relatively flat.

The southwesterly trend of the minor folds in this area might be regarded as sufficient evidence for separating this unit from other isolated sandstone units in the southern part of the quadrangle, but the folds are merely minor features, the principal dip being northeastward in the direction of pitch of the folds. Possibly such minor folds exist in other areas but have not been recognized because of the scarcity of outcrops.

Lacking any contrary evidence, this unit has been classed as Vaqueros-Temblor, largely on the basis of lithologic similarity.

Redwood Creek Area. Fine to medium conglomerates are the most characteristic rock type in the Redwood Creek area. The pebbles are largely quartz, quartzite, and pegmatite, with some gneiss and quartz diorite. They rarely attain a size of more than 6 inches. The groundmass is medium to coarse, reddish-brown to white, feldspathic sandstone with subangular grains. Sandstones and shales alternate with the conglomerate beds. The sandstones vary from fine and even-grained to pebbly beds, and include red, green, buff, gray, and white beds. Shale is not common, but a few gray and brown arenaceous siltstones are present. All these varieties of sediment occur in an area of less than a quarter of a square mile. Nowhere in the quadrangle are variations so marked and so rapid. Lenticular bedding is the rule and the unit may be a continental deposit.

The following typical though incomplete section taken in the valley at the very center of the area illustrates the rapid variations here encountered.

	Thickness in feet
Top	
Medium-coarse reddish-brown conglomerate, well cemented, with pebbles up to 2 inches in size	2
Medium-grained well-cemented white arkosic sandstone	½
Medium-grained unconsolidated arenaceous buff sandstone	1½
Finely bedded red-brown and white well-cemented sandstone	3
Gray shale	4
Coarse, brown, well-cemented conglomerate	5
Pebbly green sandstone	3½
Coarse, unconsolidated, gray-white conglomerate	6
White, medium-grained, well-sorted, arkosic sandstone	1
Medium, reddish conglomerate, well-cemented	3
Base (not exposed)	
Total	29½

The beds in this area strike N. 60° W. and dip 32° NE. The bedding, however, is irregular and discontinuous so that this determination may be inaccurate. The unit has an exposed thickness of 300 feet.

Intensely sheared Sur schists and gneisses along the northwestern margin testify to a fault contact. To the south the contact appears to be depositional, but is not exposed.

This sedimentary area is markedly different lithologically from any of the others and may well be continental in origin. It is placed questionably in the Vaqueros-Temblor.

Ventana Creek Locality. The most inaccessible and probably most interesting of the sedimentary areas in the southern half of the quadrangle is the unit exposed in Ventana Creek near the center of sec. 15,

T. 19 S., R. 2 E. Here a massive, extremely well-cemented, fine- to medium-grained arkose, rich in biotite, with scattered chips of gray shale and locally tiny stringers of calcite, overlies a dense, gray, fine-grained, cherty, algal limestone. The limestone appears to be uniform throughout its exposed thickness of 150 feet. The overlying sandstone has an exposed thickness of 650 feet. The beds strike N. 60° W. and dip 31° SW.

Well-cemented conglomerate boulders containing pebbles of quartz diorite and quartz up to 5 inches in diameter were found in the bed of the creek below the sedimentary area, but the conglomerate was not found in place.

The topographic mapping in this area is not accurate and added greatly to the difficulty of delimiting this unit. Both the limestone and Sur rocks to the northeast show intense shearing. The southern margin is not well exposed, but structural relations indicate that this contact too must be faulted.

Three small isolated patches of sandstone, too small to show on the map, were found about half a mile south of the main sedimentary unit. Their relation to the surrounding rocks could not be determined.

Here again is a sedimentary unit which bears little lithologic resemblance to the northern occurrences. The algae, however, suggest that its age is at least middle Tertiary and the unit has been doubtfully included in the Vaqueros-Temblor.

Monterey Formation—Middle-Upper Miocene

Distribution

The Monterey formation is confined to the northeastern half of the quadrangle. North of Tularcitos Creek it forms a continuous broad band from Los Laurelos Ranch southeast to Madrona Canyon. To the northwest it is exposed in road cuts, beneath the terrace gravels of the Carmel River. From the ridge east of the mouth of Anastasia Canyon another large area of Monterey sediment extends beyond the eastern margin of the map into the adjoining Soledad quadrangle. On the south side of Tularcitos Creek the formation occupies the crest of the southeastern end of Tularcitos Ridge and a few small isolated areas to the west, south, and east.

Lithology

In all except the east-central area the formation consists predominantly of finely bedded, limy and siliceous shales and cherts with occasional beds of fine-grained white sandstone and gray argillaceous shale, which become increasingly abundant near the base of the formation. The predominant rock types are organic in origin, both diatomaceous and foraminiferal shales being represented, but siliceous shales and cherts of chemical origin are also common. All of these types are intimately associated with one another. Skeletons of diatoms in a dense opaline groundmass containing occasional fragments of volcanic glass and clastic materials (quartz and feldspar) comprise the siliceous organic rocks, which are white, cream, tan, or gray in color. Compact and light in weight, they are locally soft and punky when weathered and are usually finely bedded and blocky. The foraminiferal shales are less well indurated, contain more argillaceous materials, and are finely laminated. Opaline shales and cherts occur in rhythmically banded units, the individual beds ranging from a fraction of an inch to a foot or more in

width (average 2 inches). These are often separated by thin seams of gray argillaceous shale. Brownish-gray in fresh fracture, the cherts weather to cream or yellow-buff, and break into the small angular chips which characterize the soil in areas underlain by the Monterey formation.

The sandstone, which is most abundant toward the base of the formation, is medium- to coarse-grained, locally pebbly, white, poorly cemented, and arkosic. It is very similar to the Vaqueros-Temblor sandstone in the Tularcitos area.

In the east-central area, gray and brown silty siliceous shales and argillaceous siltstones are at least as common as the organic shales. Sandstone members persist throughout the formation, the top of which has been removed by erosion. A dense, argillaceous, well-cemented, yellow-brown, fine, limy sandstone is common in beds up to 2 feet in thickness. Less commonly the medium-grained white arkose is found in beds as much as 5 feet thick.

Throughout the entire Monterey area the clastic sediments are more common near the base of the formation. Cherts and organic shales lying directly on the bedrock in some localities suggest that the younger Monterey beds overlap the older.

Near the top of the formation in the creek southeast of Casa Verde Gun Club mudcracks were found in the siliceous shale. Septarian concretions usually less than a foot in diameter are present in the shale and locally the beds have been cracked and recemented by stringers of chert.

South of Buckeye Ridge in the middle of the divide west of Sycamore Gulch, at an elevation of 1400 feet, a sliver of gray vitric tuff, 8 to 10 feet in thickness, occurs interbedded with the shales in the upper part of the formation. Herold (37, p. 1342) has published a detailed report on this rhyo-dacitic vitric tuff and suggests that it was derived from the Pinnacles area.

Large outcrops are not common in the areas underlain by the Monterey formation, and, with the variation in lithology along the strike of the formation it has been impossible to work out a complele section. The two partial sections below give some idea as to the nature of the formation.

The first section, taken in the valley south of the lower shale contact just west of Chupines Creek, is characteristic of the basal part of the formation in the Tularcitos area.

	Thickness in feet
Top	
Rhythmically banded white siliceous shale and opaline chert with beds up to 3 inches in thickness separated by narrow seams of dark-gray argillaceous mudstone	15
Fine-grained, white, limy, unconsolidated sandstone	1½
Gray siliceous shale, finely bedded	3
Finely laminated, white, diatomaceous shale	6
Gray, argillaceous shale	½
Rhythmically banded chert as above with occasional thin bed of white unconsolidated foraminiferal shale	4
Base (not exposed)	
Total	30

Outcrops are more abundant in the east-central area where many small creeks have cut sections across the Monterey sediments. None of

these, however, are large. A typical section from the small creek in the $N\frac{1}{2}$ sec. 36, T. 18 S., R. 3 E., near the east margin of the area follows:

Top	*Thickness in feet*
Buff shale	4
Yellow-brown shaly sandstone, well cemented and fine-grained	1
Rhythmically banded white opaline chert with gray argillaceous shale seams separating the ¼-inch beds	8
Blocky gray shale	3
Finely bedded, white, diatomaceous shale, punky	3½
Massive, gray siltstone, locally sandy	4
Base (not exposed)	
Total	23½

Sections in the upper part of the formation are not uncommon, but usually only the rhythmically banded cherts are exposed.

Thickness

The Monterey formation attains a maximum thickness of 1300 feet south of Buckeye Ridge. To the north the top of the formation has been removed by erosion, and the exposed thickness is less; but in the Salinas quadrangle Herold (35, p. 51) has reported 1625 feet of Monterey shales. Southeastward the formation thins to about 600 feet in the neighborhood of Conejo Creek.

In the east-central area the upper part of the formation has again been removed by erosion and the exposed thickness is only about 750 feet; but in the Soledad quadrangle Schombel (40, p. 21) reported a thickness of more than 2000 feet.

In all of the small isolated Monterey patches the formation has been deeply eroded and only a few tens of feet remain. On Tularcitos Ridge the formation is about 200 feet thick.

Relation to Adjacent Formations

The largest units of Monterey formation are parts of the large Tertiary synclines which make up the Tularcitos, Cachagua, and east-central sedimentary areas. In all of these the Monterey lies upon the Vaqueros-Temblor sandstones and in the first, beneath the San Pablo sands. At the southern end of both the Tularcitos and east-central areas the Monterey is in fault contact with the crystalline basement rocks to the southwest. Similar faulted contacts occur in several other locations. Between Chupines and Klondike Canyons, on the southeast end of Tularcitos Ridge, southeast and southwest of Conejo Creek, and north of Piney Creek, the Monterey lies depositionally on the pre-Jurassic rocks.

There is widespread evidence of overlap of the Vaqueros-Temblor sandstone by the Monterey shales. In the area between Chupines and Klondike Creeks and the area southeast of Conejo Creek, the siliceous shale and chert are separated from the older rock by a layer of medium- to coarse-grained, poorly cemented, white arkosic sandstone ranging from 5 to 15 feet in thickness. This may be a part of the Vaqueros-Temblor, but is more probably one of the Monterey sandstone units. Elsewhere the typical Monterey cherts lie directly on the pre-Jurassic rocks, suggesting overlap of the lower Monterey as well as the Vaqueros-Temblor. On the south side of the ridge in the center of the $N\frac{1}{2}NE\frac{1}{4}$

sec. 1, T. 18 S., R. 3 E., the cherts are separated from the weathered granite by only 2 feet of shaly sand.

The distribution of the formation suggests that the Tertiary seaway expanded throughout late middle Miocene time and that Monterey shales were deposited in areas not reached by the earlier seas. The Tularcitos Ridge occurrence presents an interesting problem in this connection. Since the Vaqueros-Temblor sands are present in considerable thickness on either side of the ridge but are lacking beneath the Monterey shales along the southeastern crest area, this region must either have been an island during the earlier part of the period, or else the older sandstone must have been stripped from the crest prior to the Monterey inundation. Similar relationships are to be noted in the area between lower Chupines and Klondike Creeks.

Evidence has already been presented supporting the theory that Tularcitos Ridge area was an island in the lower-middle Miocene sea. However, the suggested difference in attitude between the shale and sandstones in Trampa Canyon and the nature of the depositional contact there exposed indicate that this region may have been uplifted, mildly deformed, and eroded before the advance of the Monterey seas. Possibly both conditions existed in this area and combined to produce the relationships observed.

The contact between the Monterey formation and the younger San Pablo is exposed only in the valley southwest of Casa Verde Gun Club, an eighth of a mile east of the highway. Along the lower parts of the creek sandstone and shale are interbedded, but in the upper creek area the sandstone becomes predominant, and finally is the sole member exposed. There seems to be complete lithologic gradation from Monterey shale to San Pablo sandstone. The contact was arbitrarily mapped as the top of the last large shale bed and as such is a lithologic and not a time boundary. Elsewhere in the quadrangle the upper Monterey contact has been traced largely by soil float.

Conditions of Deposition

Much has been written concerning the conditions under which the Monterey cherts accumulated, and the present study can add little to the voluminous literature on the subject. Reed (33, pp. 203 and 224) suggests that a semi-arid climate, low surrounding land areas, and deranged drainage from the ancient land-mass "Mohavia," (which caused the detritus from this area to be deposited, as the Rosamond series, before it reached the sea), may all have been factors operating to cause the observed sparsity of clastic material in the Monterey formation. The presence of some clastic material throughout the Monterey series in the Jamesburg quadrangle indicates that normal marine sedimentation did occur during Monterey time and does not support the hypothesis of extreme climatic aridity suggested by earlier writers. Occasional fragments of volcanic glass in the shales and the vitric tuff bed near the top of the formation add weight to Taliaferro's (33) suggestion of a volcanic source for the silica. Near the top of the formation mud cracks were found within the siliceous shale supporting the shallow-water origin of the sediments suggested by Reed (26, p. 135). The overlap of older by younger beds indicates an advancing sea during Monterey time.

Although the siliceous shales overlap the older sandstones in the northeastern half of the area, indicating that the Monterey sea in this locality was more extensive than the Vaqueros-Temblor, the lack of any recognized middle-upper Miocene sediment in the southwestern half of the quadrangle suggests that the younger sea may have been confined to one of the widespread troughs in which Vaqueros-Temblor sediments accumulated. It is of course possible that Monterey seas were present to the southwest, the sediments of this age having been entirely removed from this area by subsequent erosion.

Fauna and Age

Only four fossil localities were found in the Monterey formation. These localities together with the fauna from each as determined by B. L. Clark are given below.

On road to Pizzoni Ranch ¼ mile north of Chupines Creek. 1.3 mile east and .95 miles south of intersection of 40′ parallel and northern margin of map:

Anadara n. sp. 1
Anadara n. sp. 2
Tellina congesta

North of bend in Chupines Creek .65 miles east and .5 miles south of intersection of 40′ parallel and northern margin of map:

Anadara obispoana
Venerupis n. sp.

On southwest end of Tularcitos Ridge .2 miles north and .1 mile east of northeast corner sec. 1, T. 18 S., R. 3 E., M.D.

Anadara n. sp. 1
Tellina congesta

At 1250′ contour on ridge north of Rana Creek, 1 mile N. 39° E. of Tularcitos Ranch:

Nassarias cf. whitneyi

On the basis of these megafossils Clark classes the formation as Monterey. The presence of *Nassarias* cf. *whitneyi* near the top of the shales indicates that the upper portion of the formation may be lower San Pablo (Briones) in age and again emphasizes the importance of recognizing that the formational contacts shown on the map are lithologic and not necessarily time boundaries.

Although Foraminifera are abundant in the shale no study has been made of the microfauna. Herold (35, pp. 52-53) lists six protozoa from the Salinas quadrangle and on this basis concludes that formation is near the border of the middle and upper Miocene (Luisian-Mohnian).

Several of the ranchers, particularly those in the northwestern end of the area have found and collected whalebones from float material of the Monterey formation. However, no vertebrate materials were found in place during the course of this study.

San Pablo Sandstone—Upper Miocene

In the Tularcitos sedimentary area the San Pablo sandstone occupies the shallow troughs of two synclines, one north and one south of Agua Mala Creek. The upper part of the formation has been removed by erosion so that the maximum observed thickness of 500 feet is undoubtedly much less than the amount formerly present.

A massive, medium-grained, uncemented, moderately well-sorted white arkosic sandstone is the most characteristic and widespread lithologic type in this formation. In the U-shaped valley half a mile west of 1342 hill and an eighth of a mile east of Chupines Creek a 65-foot cliff of this sandstone is exposed. Here the sandstone is massive and uniform throughout.

In the area south of Agua Mala Creek small exposures are common. The formation contains argillaceous sandstone and shales at the base near the contact with the Monterey formation. The most interesting member of the formation in this area is the dirty, gray-brown, shaly sandstone which contains abundant biotite and milky quartz chips and grains as well as decomposed biotite and hornblende gneiss fragments. Chips of siliceous shale and chert, lithologically identical with the older Monterey formation, are scattered throughout this unit, which is exposed in the road cuts south of Casa Verde Gun Club and again in the deep gullies southwest of B. M. 1589. This unit occurs near the base of the formation, but is not exposed on the northeast side of the syncline.

Only one fossil locality was found in the San Pablo sandstone, 200 yards northeast of the southern Monterey-San Pablo contact on the crest of the ridge $\frac{3}{4}$-mile north of the unnamed creek west of Sycamore Gulch. The following forms have been identified by B. L. Clark and indicate the age of the upper sandstone unit as San Pablo:

Ostrea titan
Pecten cf. estrallanus
Saxidomus sp.
Taris cf. paribis

Although no fossils, save an occasional fragment of *Ostrea titan* in the float, were found in the upper sandstone south of Agua Mala Creek, the lithologic and stratigraphic similarity of the predominant sandstone member in this area with that of the San Pablo to the north has led to correlation of the two. The heavy-mineral study lends some support to this correlation.

Quaternary System

Stream Alluvium and Terrace Gravels

The Quaternary alluvium as shown on the geologic map includes both recent floodplain sands and gravels and older terrace gravels. Floodplains have been developed along most of the creeks in the central Tularcitos belt of the quadrangle. In large part the older gravels are merely thin blankets of sediment spread across rock-cut terraces formed when recent rejuvenation caused the streams to cut below their levels. This relationship is particularly well illustrated along the highway southeast of Rancho del Monte where roadcuts expose the Monterey shale beneath the older terrace gravels and above the present floodplain of the Carmel River. The largest and coarsest of the older deposits are found at the northwest corner of the map, along the Carmel River at its junction with Cachagua Creek, and upstream along both rivers from this junction. In these areas the older stream deposits are composed largely of coarse gravels containing boulders up to 3 feet in diameter largely of Santa Lucia and Sur materials. There are some lenticular sands. Poor bedding and sorting and rapid horizontal and lateral variations are characteristic. In the northwestern area the terrace gravels are 250 feet above the present stream level. In the Cachagua area they form a steep ridge of boulders 100 feet above the present stream. In both areas the streams have again reached base level, are meandering and building a lower, narrower alluvial plain predominately of fine-grained materials. Road cuts provide good exposures in both regions.

Chupines Creek, Tularcitos Creek and most of the large tributaries flowing into the latter, contain extensive areas of stream alluvium which,

though much finer in texture than that of the Carmel River, have similarly been entrenched and left as abandoned terraces.

To the southeast occasional alluvial deposits have been formed in Conejo, Anastasia, and upper Cachagua Creeks, but the streams in this region do not show effects of rejuvenation.

In the mapping, older terrace gravels have not been separated from younger stream deposits.

On the crest of the ridge between Pine Creek and the south fork of San Clemente Creek there is a small area of unconsolidated gravel in which are well-rounded pebbles of lava. This gravel may represent a much older terrace possibly correlated with the early Pleistocene surface recognized by Trask (26, p. 173) in the Point Sur quadrangle. The areal extent of this gravel was too small to show on the geologic map.

Alluvial Fans

At the northeast corner of the area the alluvial fans which mark the margin of Salinas Valley lap over the edge of the Sur metamorphics comprising the eastern portion of the Sierra de Salinas mountain block. Typical fanglomerates, these deposits consist of red-brown unconsolidated, lenticular, poorly sorted gravels, occasional sands and infrequent shales. Boulders sometimes reach 3 feet in diameter, are usually subangular, and are almost always fragments of quartzose gneiss, which is the characteristic metamorphic type in the source area. Occasionally a granitic or quartz pebble or boulder is encountered. Since very little study was made of these deposits they have been mapped with the stream alluvium.

To the north Herold (35, p. 91) finds these deposits lying unconformably on the Paso Robles formation and concludes that they are "Pleistocene or more probably Recent" in age.

Landslide Debris

Small landslides are common throughout the Tularcitos sedimentary area. The heavy rains during the winter of 1939 caused innumerable small slides during that one year. For the most part they are typical slides with amphitheater-like cliff heads and hummocky lower surfaces. Most of them were too small to map.

Below the lava cap on the divide northwest of Madrona Canyon the lower ridge is covered with a thin layer of coarse angular disarranged lava blocks. The sandstone can be seen outcropping on the side of the ridge beneath this layer, which is believed to be the remnant of an ancient landslide. Small slides are common on the higher slopes in the lava area.

STRUCTURE

The Jamesburg quadrangle lies entirely within the great central band of the California Coast Ranges which is the crystalline zone referred to as "Salinia" by Reed (33, p. 12). To the northeast and southwest this zone is bounded by the San Andreas and Sur-Nacimiento faults respectively, which separate "Salinia", underlain by granite and metamorphic rock, from zones in which the pre-Tertiary basement rocks include the Jurassic Franciscan. No Jurassic rocks, with the exception of the serpentine intrusives, outcrop within the limits of the Jamesburg quadrangle.

Both structurally and physiographically the quadrangle may be divided into three northwestward-trending belts. The southwestern belt is composed largely of igneous and metamorphic rocks, contains isolated small patches of Tertiary sediments, and is cut by large northwestward-trending fault zones and minor cross-faults. This belt may be termed the Santa Lucia; since the crest and steepest parts of that range are included in the area.

To the northeast the Santa Lucia block is bounded by the Cachagua and Bruce Ranch faults, which are believed to be parts of the same fault zone. Northeast of the fault zone lies the lowland area which makes up the central belt of the quadrangle, the "Tularcitos belt." Sedimentary rocks comprise a large portion of this central block although the older igneous and metamorphic basement rocks are abundantly represented. Both folding and faulting have been active in the Tularcitos block and one major fault zone, the Tularcitos fault, extends across almost the entire area.

The northeastern belt, called the Sierra de Salinas, is bounded on the northeast by Salinas Valley, the boundary being marked by a very pronounced break in slope. The southwestern boundary is not clearly marked by any structural feature except the Paloma fault in the east. Elsewhere the boundary is arbitrarily taken as the edge of the sedimentary area, making this block one composed entirely of igneous and metamorphic rocks, without any mapped structural features save those in the Sur series.

The northeastern corner of the area is occupied by Salinas Valley which forms a fourth structural and physiographic unit. Since so little of this area occurs within the Jamesburg quadrangle no detailed study was made of it in the course of this investigation.

Faulting

Northwestward-trending faults are the major structural feature of the Jamesburg quadrangle, as they are throughout the entire California Coast Ranges. Within the Jamesburg quadrangle there are nine such fault zones, all but three of which have been traced for at least 5 miles. Six of these faults, including three which have been traced only short distances in the Jamesburg area, continue into adjacent quadrangles.

Most of these are reverse faults of high dip, usually more than 65°, and large displacement. Locally the faults steepen and are vertical or high-angle normal faults. Branching and change of dip are common in most and, although they are shown as lines on the map, each fault is really a zone, often several hundred feet wide, throughout which crushing effects can be recognized.

This major group of faults is cut, and locally displaced, by a series of vertical or steep normal faults which are in part contemporaneous with, and in part younger than the larger faults. Most of these faults trend northeastward and have relatively small displacement.

In the areas occupied entirely by the Santa Lucia and Sur series it is almost impossible to trace faults. The massive character of the intrusive rock, the lack of any recognizable sequence in the metamorphics, and the density and persistence of the brush cover, which largely limits exposures to the lower parts of the stream canyons, all combine to make the accurate mapping of faults extremely difficult. That many faults

do exist in this area is clear, for never does one travel many miles without seeing crushed and fractured metamorphic and igneous rocks. The faults herein described have been recognized and traced largely by the anomalous juxtaposition of sedimentary rock units, as can be seen by a glance at the geologic map. Once a fault is so located and its attitude determined, it can be traced for some distance in the basal complex, as has been demonstrated in the case of the Redwood fault. For the most part, time was not available to follow faults through the crystalline terrain and consequently few of the faults have been traced across the entire quadrangle. In some cases, however, sufficient evidence has been obtained to justify joining isolated faults, and considering them as a unit.

Northwestward-Trending Faults

Redwood Fault. Trending northwest across the southwestern corner of the map, the Redwood fault is the link between the North Fork fault mapped by Reiche (37, p. 154) in the Lucia quadrangle, and the Palo Colorado fault in the Point Sur quadrangle, mapped by Trask (26, p. 164). The fault as so mapped extends for 25 miles from the Pacific Coast to the heart of the Santa Lucia Range.

Within the 6-mile stretch mapped in the Jamesburg quadrangle, the fault is best exposed in and near Redwood Creek, where the plane dips about 85° NE., and the fault zone has an exposed width of 150 feet of crushed and broken rocks of the Sur series, largely schists. The fault here marks the northern boundary of the Vaqueros-Temblor (?) sandstone. The Redwood is a reverse fault, and the northeast side, occupied by schists of the Sur series, is upthrown. The displacement is at least 2000 feet, as estimated by the absence of sediment on Pine Ridge to the northeast. Trask estimates the displacement as 5000 feet. Reiche places the minimum at 1000 feet.

With much difficulty the fault has been traced almost continuously from this area to the western margin of the map. Northwest of Redwood Creek the fault passes through a notch in the divide and then follows down the steep creek to the west. Outcrops are not abundant in this creek, but in the next unnamed tributary of the Sur a shear zone was found at the mouth of the straight creek in the center of the eastern margin of the SW$\frac{1}{4}$ sec. 24, T. 19 E., R. 2 E. This fault zone can be followed up the creek to the northwest. The intense shearing at the mouth of this creek and the lack of a shear zone to the north on the strike of the fault as traced from Redwood Creek, suggest the presence of a cross-fault in this region displacing the Redwood fault some quarter of a mile to the south and possibly explaining the sudden turn of the eastern tributary creek. The shear zone can be traced northwestward to the saddle of the next ridge, but is then lost in the basement complex.

East of Ventana Creek the fault divides, and a small unit of Vaqueros-Temblor (?) sediments has been dropped down into the basement complex between the branch faults. The northern branch is well exposed in Ventana Creek and has the same dip as at Redwood Creek, that is, 85° NE. The southern branch is not exposed, but its presence is indicated by the abrupt termination of the southwestward-dipping sandstone against the Sur schists. The minimum throw on the southern branch is 1000 feet. On the northern branch it may be 2500 feet.

An eighth of a mile south of the 3565 hill near the western margin of the map the fault is believed to pass through the saddle west of the

3565 peak. Sheared schist is exposed in the valley just west of the saddle.

The fault as here mapped does not connect directly with Trask's Palo Colorado fault, but the discrepancy is not beyond the limits of error imposed by the difficulties of mapping. Trask's location is shown as inferred.

South of Redwood Creek, sheared schist and quartzites are exposed in gullies and trail cuts along the strike of the fault, and direct connection with Reiche's North Fork fault is assured.

Church Creek Fault. Near its center, the Santa Lucia belt is cut by a large fault zone first named by Herold (see Reiche 37, p. 155) the ''Church Creek fault'' for its occurrence in the southern part of the region. The name was adopted by Reiche (37, p. 155) who applied it to a fault which he traced $3\frac{1}{4}$ miles in the Lucia quadrangle to a point where it intersected the Willow Creek fault. From the southern margin of the Jamesburg map the fault has been traced continuously for 8 miles to the head of Pine Valley. Here it is offset to the south and split. It then continues to the western margin of the map, where it connects with the inferred Devils Peak fault in the Point Sur quadrangle (Trask 26, p. 166). Its total length is more than 21 miles.

In the southern part of the Jamesburg quadrangle the fault marks the northeastern margin of the Church and Pine Creek Vaqueros-Temblor sandstone unit. Sheared and crushed rocks of the Sur series, which have been thrust over the Tertiary sediments from the northeast, are exposed at frequent intervals in the small tributary creeks all along the fault zone. Waterfalls are common in most of these creeks along the strike of the fault. In the southern Church Creek region the fault dips approximately 65° NE., but the plane steepens farther north, and appears to be nearly vertical in the Hiding Creek area. A minimum displacement of 1800 feet is indicated in this region.

In the SE$\frac{1}{4}$ sec. 13, T. 19 S., R. 3 E., a vertical west-northwest cross-fault offsets the Church Creek fault. The offset of the depositional sandstone contact by this cross-fault indicates a displacement of 1300 feet.

Just north of the head of Pine Valley the fault swings to the west and cuts out the sandstone, but the sheared Sur series, exposed in the east wall of upper Hiding Creek, make mapping of the fault possible for some distance beyond the sedimentary area.

One mile to the southwest, two other faults mark the eastern margins of the two Carmel Vaqueros-Temblor sandstone patches. The strike of these faults is approximately the same as that of the Church Creek fault and they are believed to be a part of the same fault zone.

Shear zones along the eastern of these two faults are exposed in Hiding Creek, along the trace of the fault near the ridge top and in the small Carmel tributary valley beyond. This fault marks the margin of the sandstone area, appears to be almost vertical, and has a displacement of at least 1500 feet. The sandstone does not outcrop on the ridge south of Hiding Creek. Apparently a cross-fault, trending about parallel to the creek, cuts the main faults in this locality. The juxtaposition of the sedimentary and crystalline rocks is the only evidence of this cross-fault, for the shear zones exposed in Hiding Creek may be related to the major fault zone. It seems likely that the cross-

fault, possibly contemporaneous in age, has caused displacement of the Church Creek fault zone from the head to the middle of Hiding Canyon.

The western fault is exposed in the mouth of Hiding Creek, on the ridge nose to the north, and again in the Carmel Valley. Closely paralleling the eastern fault, it is nearly vertical, but if the two sandstone patches are part of the same unit the displacement on this fault is only about 500 feet.

West of the Carmel River the Church Creek fault is believed to follow up the straight stream valley as shown. Outcrops are not abundant, but there is some local evidence of shearing. In the headwaters of this creek just below the divide south of Uncle Sam Mountain a sliver of middle Eocene sandstone has been faulted down between the older rocks and the few outcrops seen suggested that the fault here branches and surrounds the sediment.

From this point to the western margin of the map the fault marks the approximate contact between the quartz diorite and Sur series, although the metamorphics are so full of granitic material in this area that a sharp dividing line cannot be drawn between the two pre-Jurassic units. Sheared crystalline rocks of both types have been found in the larger creeks along the strike of the fault.

Miller Creek Fault. From the head of Calaboose Creek to Hennicksons Ridge 7 miles to the northwest, the Santa Lucia block is cut by the Miller Creek fault, so designated because it is approximately parallel with the creek of that name. Throughout most of its length the fault forms the eastern margin of the Miller Creek Vaqueros-Temblor sandstone unit. In the south the fault dips about 70° E. To the north it steepens to almost 90°. The shear zone is well exposed in many of the small tributary creeks. Older rocks have ridden up over the sedimentary rocks from the northeast and the fault is a reverse type. The displacement is at least 2500 feet.

In two localities at either end of the main sandstone unit the fault branches, and slivers of sedimentary rock have been dropped into the older basement rock between these branches. In the Chews Ridge area the southern branch is well exposed in the steep head of Miller Creek. Waterfalls and what appear to be hanging tributary valleys suggest recent movements along this fault. The pinching out of the sediments to the northeast indicates that the branches have reunited.

An eighth of a mile north of the center of sec. 26, T. 18 S., R. 3 E., the main sandstone mass ends abruptly in the steep tributary creek, apparently cut off by a west-northwest-trending cross fault. The Miller Creek fault appears to be offset slightly, then branches to bound both sides of the sandstone sliver in the north-central part of the section. This sliver is separated from the main sandstone mass by a thin band of intensely sheared Sur schist. The northern branch of the fault is well exposed as a nearly vertical crush zone 50 feet wide. The presence of the southern branch is inferred by the abrupt termination of the sediment to the west. The sandstone can be traced across the crest of the ridge where it pinches out, apparently as a result of the rejoining of the branch faults.

North of this point the fault is obscured in rocks of the Sur series, but it reappears in the NE¼ sec. 22, T. 18 S., R. 3 E., where, as a vertical

fault, it forms the eastern margin of the lower-middle Miocene sandstone unit exposed on the southeastern end of Hennicksons Ridge. Farther north the fault is again lost in the basement complex.

Blue Rock Fault. The Blue Rock fault, so named because of the serpentine plugs which have been intruded along the fault zone, is a continuation of the San Clemente thrust mapped by Trask (26, p. 163) in the Sur quadrangle to the west, and as such has a length of at least 8 miles. Nowhere in the Jamesburg quadrangle is the fault well exposed, although sheared and broken metamorphics and intrusives outcrop in small isolated patches along the strike of the fault. The best exposures are on the south bank of San Clemente Creek, in Pine Creek, and in the environs of the serpentine plugs. From the mapping, the fault appears to be nearly vertical. No measure of the displacement could be made.

Throughout most of its length the fault marks the boundary between the Sur series to the northeast and the quartz diorite to the southwest, but just south of Blue Rock Ridge the intrusive contact between these two swings south away from the fault. The principal evidence for the continuation of the fault is the alignment of the serpentine intrusions, near each of which are sheared rocks of the Sur series. South of Rattlesnake Creek the fault is lost in the Sur metamorphics which occupy both sides of the fault plane.

In the Jamesburg quadrangle the southwest side of the fault has moved up relative to the northeast, bringing the intrusives into contact with the metamorphics of the Sur series. In the Point Sur quadrangle, Temblor sandstone * occupies the southwest, the Sur series the northeast side of the fault, indicating that the movement was the reverse of that in the eastern area. Since the serpentine plugs are believed to have been forced up along a zone of weakness, it seems likely that pre-Jurassic movement resulted in the upward displacement of the southwest (quartz diorite) side. The more recent late Tertiary movements dropped this same side of the fault.

This fault is particularly interesting not only because it shows reversal of movement, but more especially because it suggests pre-Jurassic faulting in the area and indicates the possibility that old structures may have, in part at least, guided the more recent Tertiary diastrophism.

Cachagua and Bruce Ranch Faults. The margin between the Tularcitos and Santa Lucia blocks is marked by two faults which are believed to be a part of the same fault zone. Between the two is a 3-mile zone occupied by Sur metamorphics through which the fault could not be traced. It seems likely, however, that detailed study might serve to connect these two zones and they are, therefore, considered together.

The Cachagua fault, so named because it marks the western margin of Cachagua Valley, is best exposed at Camp Syndicate in the north wall of the Carmel River an eighth of a mile west of the eastern margin of sec. 31, T. 17 S., R. 3 E. The fault plane is nearly vertical and the crushed and broken zone in the Sur series, and to a lesser extent in the sandstone, is about 50 feet wide as exposed throughout the height of the

* Trask's mapping suggests that the nose of this sandstone unit extends into the Jamesburg quadrangle; however, if present, it is not exposed within the limits of the quadrangle and has not been mapped.

75-foot cliff. Displacement along the fault must be at least 1750 feet, the west side being upthrown.

To the north the fault is not exposed, but has been traced as the southwestern margin of the Cachagua Vaqueros-Temblor sandstone unit. It trends slightly west of north for about three-quarters of a mile then turns sharply to a northwest trend which it maintains throughout the rest of its length. The almost east-west vertical cross-fault which marks the northern margin of the sandstone unit does not seem to offset the major fault. Across the lake, formed by the dam on the San Clemente River, and directly on the strike of the fault, a thin sliver of sandstone is exposed beneath the terrace gravel on the nose of Long Ridge and in the valley between Long and Osborn Ridges. This is believed to be a fault sliver between two branches of the Cachagua fault. The adjacent Sur series shows intense shearing effects. The fault is believed to continue to the northwest up this nearly straight creek, but could not be traced through the intrusive area. Probably the fault continues on to the edge of the quadrangle and joins the unnamed fault mapped by Trask (26, p. 163) south of Vasquez Knob in the Point Sur quadrangle.

South of Camp Syndicate, sheared rocks all along the base of Blue Rock Ridge suggest that the fault cuts across the ridge nose. The sandstone exposed in Carmel Valley beneath the terrace gravels dips northwestward and is believed to have been dragged up along the fault plane. Across the Carmel River near the center of sec. 4, T. 18 S., R. 3 E. sheared metamorphics in the steep stream valley suggest that the fault continues across Hennicksons Ridge. Minor shear zones are exposed at other places along this ridge above the break in slope, but no good exposures occur until Baranda Creek is reached. Here intensely sheared schists outcrop in the north wall of the creek. The continuation of the fault from Camp Syndicate to Baranda Creek is uncertain.

A fault trending northeastward intersects the Cachagua fault in Baranda Creek. This cross-fault forms the southeast margin of the sedimentary unit in this area and brings the Sur rocks up against the sandstones. The Cachagua fault may be offset by this cross-fault, but its continuation could not be found to the southeast in the Sur complex.

Three miles southeast of Baranda Creek the Bruce Ranch fault continues on about the same strike as the Cachagua, and is probably a part of the same fault zone. The Bruce Ranch fault is not well exposed, but the sheared Sur rocks in the gulley east of the ranch attest to the presence of a fault, which accounts for the southwest termination of the main sandstone unit.

The small sandstone unit to the south is poorly exposed and its relationships are not well understood. If it is a continuation of the sandstone of the Bruce Ranch area, and is not itself faulted to the east, the displacement on the Bruce Ranch fault in this area is limited to 250 feet.

The eastern margin of the main sandstone of the Bruce Ranch region is also believed to be faulted, but the shear zone found in Anastasia Canyon is on the continuation of the western fault which farther to the southeast terminates the sandstone unit of Bear Trap Canyon. Sheared rocks of the Sur series and the presence of small isolated sandstone units within the shear zone indicate the fault in this area, where the displacement is about 1500 feet.

Southeast of Bear Trap Canyon the fault is again lost in the Sur series, but a shear zone was found on the strike of the fault in the next creek. Intense shearing in the steep tributary of Piney Creek marks the continuation of the fault which near the western margin of the map brings the basement complex up against the Tertiary sediments. Schombel (40, p. 37) in the Soledad quadrangle has mapped the fault (called by him the Arroyo Seco fault) a mile farther to the southeast where it turns abruptly and continues almost due south for 4 miles.

This fault zone, if continuous into the adjoining quadrangles both east and west, has been mapped for an overall length of at least 25 miles.

Tularcitos Fault. Throughout almost the entire width of the quadrangle the central Tularcitos belt is cut by a large fault here named the Tularcitos fault because of its topographic expression in the steep northern slope of Tularcitos Ridge. The fault has been traced for about 14 miles, but to the northwest is buried beneath the Carmel Valley alluvium.

The fault is nowhere well exposed, but parts of the shear zone are exposed in numerous places, notably along the base of the steep northern face of Tularcitos Ridge. The small creeks a quarter of a mile north of secs. 19 and 20, T. 17 S., R. 3 E., contain the best exposures of the sheared quartz diorite, but in the creeks all along this slope sheared outcrops are common. If this steep slope is an eroded fault scarp the relatively recent displacement must have been approximately 1000 feet.

Northwest of 626 B. M. at the junction of the Cachagua and Jamesburg roads, road-cuts display Monterey shale which has been fractured, dragged, and locally overturned along the fault. The fault has been traced to the northwest as the contact between the shale and the crystalline rocks. The only other exposure of the zone itself is in the creek along the northern margin of sec. 1, T. 17 S., R. 2 E., where both the quartz diorite and shales have been intensely fractured.

East of 626 B. M. the fault is believed to branch, one branch following the foot of the steep north slope of Tularcitos Ridge, the other following the lower margin of the ridge just above Tularcitos Creek, possibly extending out under the stream alluvium. Three-quarters of a mile east of the benchmark, fractured and contorted shale beds are exposed in a road-cut on the south side of the creek. The ridge behind the cut is composed entirely of igneous materials and the isolated outcrop of shale is believed to be in the fault zone. Overturned, fractured, and steeply dipping shale beds are exposed in the road-cuts all the way to the benchmark.

To the southeast no outcrops were found to substantiate the continuation of the fault. The lower part of Tularcitos Ridge is covered with a layer of alluvial material. Exposures are confined to the lower parts of the creeks close to the level of the Tularcitos flood plane. Although sandstone and shale fragments do occur on the flat lower part of the ridge, no outcrops of sedimentary rock were found. All outcrops were of quartz diorite. It seems reasonable to account for the lack of sediments in this area by inferring that the branch fault continues along the lower ridge front about parallel with the creek.

Across Tularcitos Creek the shale is exposed in numerous road cuts and the dips, while not extreme, are considerably greater than attitudes

obtained a little way to the north, suggesting that drag along the fault may have steepened the dips in this area.

A quarter of a mile west of Casa Verde Gun Club the intense shearing of the quartz diorite exposed in the stream canyon and the steepened dip of the shale to the west again certify the presence of the fault. The branch fault is believed to here rejoin the major fault, which swings to the south and cuts across the western end of Tularcitos Ridge. At the crest of the ridge the steeply dipping shale to the northwest has been dropped against the almost horizontal shale which occupies the ridge crest. South of Conejo Creek this identical relationship again occurs. Here we can get an estimate of the throw of the fault, which must be at least 1250 feet. In the cut on the north side of the Jamesburg road, the intensely sheared quartz diorite is well exposed.

In the southeast corner of sec. 5, T. 18 S., R. 4 E., the fault cuts out the shale member and continues on, marking the contact between the Vaqueros-Temblor sandstone and Santa Lucia quartz diorite. Near the eastern margin of sec. 9, T. 18 S., R. 4 E., it is terminated by a cross-fault trending northwestward. Farther to the southeast on the strike of the Tularcitos fault, the Paloma fault continues the same zone, but the movement is just the reverse of that of the Tularcitos fault.

Since the fault plane is not exposed, the attitude of the fault can be inferred only from the mapping. Along Tularcitos Ridge the main fault seems to dip steeply to the southwest, but at the southeast end of the ridge a northeast dip is suggested. South of Madrona Canyon the fault was traced largely by float, but its trend again suggests a southwest dip. Northwest of B.M. 626 the fault seems to maintain the southwest dip until it crosses the Carmel River, beyond which it again appears to dip to the northeast. Since everywhere the southwest side of fault has moved up relative to the northeast side, the fault is reverse throughout most of its length, but normal at either end. In all cases it has a steep dip.

Paloma Fault. Because of the excellent exposure in the wall of Paloma Creek, the thrust fault at the west margin of the quadrangle has been named the Paloma fault. The fault plane dips 80° NE., and the shear zone, which has been quarried for road metal, is at least 75 yards wide. Granodiorite has here been thrust over the Monterey shales which are shattered and broken, but apparently little dragged along the fault. The displacement is about 1300 feet.

The fault has been traced southward for a short distance into the Soledad quadrangle by Schombel (40, plate IX).

From Paloma Creek the fault can be traced westward, abruptly terminating the sedimentary structures as far as the saddle below the high 2700-foot peak. In the valley south of this peak the sandstone has been dragged to a steep 70° dip, and outcrops beneath the intrusive, although the fault itself is not exposed.

Beyond this saddle the fault swings to the north for three-quarters of a mile, then turns back to its northwest course. Just west of the Foster Ranch a northeast-trending cross-fault intersects the Paloma fault and displaces it to the east where it can be followed for another half mile as the margin of the sandstone patch before being lost in the intrusive basement rocks. The northeast-southwest cross-fault in secs. 9 and 10, T. 18 S., R. 2 E., may account for the disappearance of the fault to the

northwest. While the sandstone-quartz diorite contact in the N½ sec. 10 is on the strike of the fault, this contact is depositional. Possibly the cross-fault took up the movement on both the Paloma and Tularcitos faults.

Stephani Fault. In the steep road-cut half a mile south and slightly east of Camp Stephani, a thrust fault is exposed. A granite mass has been pushed up from the north over a massive white arkosic sandstone believed to be Vaqueros-Temblor in age. The fault zone is not wide, and, though the granite is intensely fractured, the sandstone shows little effect of shearing, except for drag, which has locally steepened the southwest dip.

Across the Carmel River to the west, the fault cuts out the sandstone, and the intrusive is in contact with Monterey shales, which show profound shear effects. West of Camp Stephani the fault disappears under the alluvium of Carmel Valley.

East of the road-cut exposure, the contact was traced by float as the boundary between the granitic rock and the sandstone. In Chupines Creek the fault again disappears beneath stream alluvium. Lack of exposures, and more especially the absence of any definite and recognizable sequence in the Monterey shale which occupies the ridge to the east, made it impossible to determine whether or not the fault continues southeast of the creek. No evidence for such continuation was found. Nor was there any evidence of a cross-fault to terminate or offset the Stephani fault along the Chupines Creek valley.

This short thrust has an estimated displacement of 750 feet. It dips 60° NE.

Del Monte Fault. In the northwestern corner of the area the sedimentary structures are terminated against a mass of granite which occupies the high ridge behind Rancho Del Monte. The contact must be faulted, but the fault is not exposed. In the Salinas quadrangle Herold (35, p. 121) has found evidence for this fault and traced it for half a mile as the Laureles fault. In the Jamesburg quadrangle the contact between the granite and sediments has been traced for almost 2 miles, and the mapping suggests a southwest dip and normal faulting. A minimum displacement of 600 feet is indicated.

The Del Monte fault is terminated on the southeast by a cross-fault. Possibly the movement on the Del Monte was transferred to the cross-fault. Although Herold (35) does not map this cross-fault, the best evidence for its existence was found in the offset sandstone contact in the Salinas quadrangle.

Chupines Fault. A quarter of a mile above the sharp bend in Chupines Creek a vertical northwest-trending fault enters and follows the creek valley. Although the fault is not exposed, the stratigraphic relationships give ample proof of its existence. The sedimentary rocks which occupy the northern bank of the creek are completely lacking to the south. The granite near the bend in Chupines Creek terminates sharply against the folded sedimentary rocks to the northeast. Farther to the northwest, the shale appears to dip under the sandstone which butts against them. Beyond the 40-minute parallel, Vaqueros-Temblor sandstone occupies both sides of the fault. Since no definite stratigraphic section was worked out in this unit, the continuation of the fault could

not be definitely established. It is believed, however, that there are differences in the sandstone units on either side of the projected fault zone. Directly on the strike of the Chupines fault in the Salinas quadrangle Herold (35, p. 121) has traced the Buckeye fault for 2 miles to a point where it joins the Calera fault, which continues on the same strike to the eastern margin of the northern quadrangle.

To the southeast the Chupines fault is lost in the Sur series.

Although the fault plane is not exposed, the mapping indicates that it is a steeply dipping normal fault. The displacement along the fault is at least 650 feet.

Cross-Faults

In addition to the major northwest-trending faults there are a series of minor, usually relatively small faults, most of which trend northeastward, but a few of which trend east-northeast or west-northwest. Few of these faults have been traced more than a mile, many of them only a fraction of a mile. Some are steeply dipping normal faults, but most are vertical. In some the northern side is upthrown, in some the southern, and in a few there is evidence of a horizontal component in the displacement. The displacement on most of these faults is small in comparison to that of the major faults.

Many of these cross-faults are contemporaneous with the major faults and in many cases the displacement on major fractures may have been taken up by the cross-faults. Locally the cross-faults offset the major faults, and are definitely younger in age.

Evidence for these cross-faults is chiefly stratigraphic. Shear zones are exposed locally, but most of the faults have been recognized and traced on the basis of structural relationships between Tertiary sediments and the basal complex.

Twelve cross-faults have been mapped. The location and characteristics of most of these have already been given in the preceding section, since almost all of the cross-faults cut major faults. Three, however, have not yet received attention.

On the south side of Tularcitos Ridge just east of Trampa Canyon, a vertical cross-fault offsets the lower depositional sandstone contact. The north side of this fault is upthrown, displacement being about 800 feet. The fault could not be traced north or south for any distance.

Southeast of the Casa Verde Gun Club a normal fault dipping about 50° S., and trending east-northeast, offsets the sedimentary contacts. Sheared sediments, especially a peculiar broken mass of shale and sandstone, (apparently a fault breccia) near the eastern San Pablo contact, and the presence of Monterey shale above the San Pablo sandstone, attest to the presence of the fault. The displacement is 500 feet, the northern side being upthrown.

On the south side of Buckeye Ridge a vertical cross-fault with a northeast strike offsets the sedimentary bands. Here the southern side is upthrown and the displacement amounts to 925 feet. Again the fault could not be traced beyond the region of offset rock units. The marked change in trend of the axis of the large Tertiary syncline south of Buckeye Ridge suggests that the fault may continue to the southeast, and there is a possibility that this fault may be the steepened continuation of the Stephani thrust. This cross-fault has been named the Buckeye fault.

Age of Faulting

Both the major northwest-trending and the minor cross-faults affect the youngest fossiliferous rocks of the area, the San Pablo upper Miocene sandstone. Throughout most of the area the topography has little relation to the faulting, with the possible exception of the steep fronts of Blue Rock, Hennicksons, and Tularcitos Ridges, where recent movements may be indicated.

In the Sur quadrangle these same faults, or rather their continuations, cut lower Pliocene conglomerates (Trask 26, p. 171) and must therefore be at least Pliocene in age.

Evidence has already been cited to support the idea of earlier movements along the Blue Rock fault. Here such movements must have been pre-Jurassic if the serpentine plugs are Jurassic in age and their location controlled by the fault zone. Faulting in the Sur series has been noted in a previous section. Many of these faults may well be of pre-Jurassic age. Possibly the Tertiary fault pattern was largely determined by older lines of weakness developed in pre-Jurassic time during or after the emplacement of the Santa Lucia batholith.

The cross-faults are believed to be in part contemporaneous with and in part younger than the major faults.

There have been at least two, and possibly more, periods of faulting in the Jamesburg quadrangle. Earlier faulting, pre-Jurassic in age and possibly including several distinct periods, may have controlled the major Plio-Pleistocene movements. Fairly recent movements seem to be indicated locally.

Folding

The Tertiary sediments throughout the quadrangle have been compressed into a series of folds which have been greatly complicated by faulting. Lack of exposures, the massive character of the sandstone units, and the lack of any constant and recognizable stratigraphic sequence within these units, has made it impossible to recognize any but major structures within the sandstone areas. The finely bedded Monterey shales, on the other hand, aid greatly in the recognition of folded structures, and most of the smaller structures have been worked out in this unit.

The possibility of minor angular discordance between the Vaqueros-Temblor sandstone and the overlying Monterey shales has already been discussed. Generally, the entire Miocene sequence seems to be conformable and the structures worked out in the Monterey formation may safely be applied to the whole series.

The Tularcitos and east-central sedimentary areas show the most pronounced folding, as is apparent from a glance at the geologic map. In both of these areas the major structural elements are synclines locally flanked by less well-defined anticlines. Superposed on these major structures is a series of smaller folds. The predominant trend is northwest, the predominant pitch southeast, in both the major and associated minor folds.

The largest of the synclines occupies the central portion of the northwestern quarter of the map and includes all three of the Miocene formations. It has been modified by the Del Monte, Stephani, Tularcitos, and Buckeye faults, and to the northeast is flanked by a broad anticline. Asymmetric, with a steeper northeast limb, the syncline is broad and open

in form. Drag along the Tularcitos fault has locally steepened the southwest limb. Dips generally decrease rapidly toward the center of the fold, which pitches to the southeast at a low angle.

To the north, the axis of the syncline seems to turn from northwest to west-northwest. This may possibly be related to movements along the continuation of the Buckeye fault.

In this area there are innumerable folds in the Monterey formation ranging from a few feet to a fraction of a mile in width. Only the larger and more persistent of these have been mapped.

South of Agua Mala Creek there is a second large syncline within the Tularcitos sedimentary area. Here too, all three Miocene units are present. In the neighborhood of Madrona Canyon the Tularcitos fault cuts across the northwest-southeast axis of the fold. Along this fault the crest of the adjacent anticline has ridden over the southwest limb of the syncline both on Tularcitos Ridge and on the ridge south of Conejo Creek. South of the Casa Verde Gun Club a cross-fault has greatly modified the central part of the syncline.

In general the structure, like that to the north, is asymmetric with a steep northeast limb, but locally drag along the Tularcitos fault has so steepened the southwest limb as to reverse the asymmetry.

No minor folds have been recognized in this syncline, but the closure of the San Pablo formation both to the north and south suggests that the structure in this region is that of an elongated basin. Between Tularcitos and Agua Mala Creeks the syncline appears to die out. Apparently the strength of the forces causing the folding in the Tularcitos area varied along the strike of the folds leading to the development of broad shallow cross structures; a syncline to the south with its axis just north of Conejo Creek, an anticline with its axis between Tularcitos and Agua Mala Creeks, and a long asymmetric syncline with its axis near Rana Creek and gentle limb rising slowly to the northern end of the sedimentary area.

The third of the major synclines is in the east-central area, does not include the San Pablo formation, and is separated from the northern synclines by the cross-fault north of the Jamesburg school. The broad shallow syncline pitching to the southeast is flanked by a narrow anticline to the east, and both structures are cut by the Paloma fault. To the southwest the Bruce Ranch fault terminates the syncline near the eastern margin of the map.

Many small folds were recognized in the Monterey formation within this major syncline. Only the more persistent of these have been mapped.

North of Chupines Creek there is a small synclinal area, again with a northwest strike and a southeast pitch. This syncline has been faulted down against the adjoining anticline to the west along the Chupines fault, which, to the east, cuts across the synclinal axis and brings the pre-Jurassic rocks into contact with the folded Monterey and Vaqueros-Temblor sediments.

In the southeastern end of the Cachagua sedimentary area a series of broad, shallow, deeply dissected folds are believed to connect with the major structures to the east. Cachagua Creek cuts the axis of a small anticline, the flanking synclines being preserved in lower

Baranda Creek and on the ridges on either side of Tramp Canyon. The shales on the crest of Tularcitos Ridge mark another anticlinal crest.

No folded structures were definitely determined in the rest of the Cachagua area, but to the northwest three small patches of Monterey shale probably mark the continuation of the trough of the western syncline noted above.

In the Carmel-Hiding Creek sandstone area broad gentle folds are well exposed. Here the folds trend northeastward and pitch to the northeast. They are, however, only minor flexures in the general northeast dip of the sediments.

No folded structures were worked out in any of the other sandstone areas of the southwestern half of the quadrangle. In some areas exposures were lacking. In all areas the sandstones were either massive or lenticularly bedded and lacked any horizon which could be used as a marker bed in the determination of structural details. Homoclinal dips seem to be characteristic of all these units. The sediments may have been tilted as a result of faulting, or they may represent remnants of previously extensive and broad folds merely modified by the faulting. The latter explanation is favored.

Evidence has already been cited for several possible ages of folding. The probability of pre-Jurassic folding in the Sur series has been suggested, and the possibility of minor warping after the Vaqueros-Temblor and before Monterey deposition cannot be precluded. The main folding, however, affects all of the Miocene rocks of the Jamesburg area and must be post-Miocene. In adjacent quadrangles Pliocene rocks are also involved, and the major folding is, therefore, believed to have been Plio-Pleistocene. Since the faults locally cut the folded structures, folding must have preceded faulting.

GEOMORPHOLOGY

Most of the surface of the Jamesburg quadrangle is in the early mature stage of the erosion cycle, but four markedly different physiographic areas have been recognized. These correspond in general to the four structural belts outlined above.

Santa Lucia Area

The most youthful physiographic area occupies most of the southwestern half of the map. This is the Santa Lucia mountain area, the most rugged part of the quadrangle with a maximum relief of more than 4500 feet. Here the canyons are deep and V-shaped, the ridges high, steep, and narrow crested. Waterfalls and rapids abound, and the entire region is so intricately dissected that there are few flat areas of any appreciable extent.

For the most part the streams in this region are permanent, although many become mere trickles during the dry season, and a few dry up entirely. An interesting characteristic of these streams is their tendency to flow underground for short distances and then reappear at the surface. Only a few of the streams have reached base level, but active erosion is largely confined to the high-water stage during the winter and early spring after which, as the streams decrease in volume, they deposit their loads, to be picked up and moved again the next year. A large part of the erosion seems to be confined to times of excessive

rain and the canyons are commonly strewn with large boulders which the streams are unable to move even during the normal high-water stage. The author can bear witness to the effects of cloudbursts in this area. Pine Creek was visited during the first, and again during the last summer spent in the field. Between these times a cloudburst in the headwaters area had so increased the power of the stream that its action in the lower canyon made the region almost unrecognizable. Where there had been a modest flood plain, only a great pile of boulders, trees, and coarse gravel remained. The valley which on the first visit had been easy to ascend, had become almost impossible to follow.

The larger streams in the area, of which the Sur and Carmel are the master streams, have reached base level in their lower parts where they meander across narrow flood plains. The clear waters of the streams, large and small, show that they are eroding only very slowly. Probably their valleys were cut during a time of more humid climate.

There is little suggestion of uniformity in the narrow ragged ridge crests which constitute the upland area. No old erosion surface is recognizable and if such a surface was once present it must either have been a surface of considerable relief or else it has been completely destroyed by recent erosion.

To the west, in the Point Sur quadrangle, Trask (26, p. 173) has recognized a surface of low relief in the neighborhood of San Fransquito Flats. The discovery of unconsolidated gravels containing well-rounded lava pebbles on the ridge between Pine Creek and the south fork of San Clemente Creek suggests that this flat ridge-crest may be a portion of the post-Pliocene surface recognized by Trask. It seems likely that Long Ridge may also have been part of this old surface.

The streams throughout the southwestern half of the quadrangle show little relation to structure. A few, for example Tassajara, Church, and Miller, follow the northwest-southeast structural trend for some distance, but even these ultimately turn and flow almost at right angles to the structures.

Even the relatively weak sandstones show only minor effect in controlling stream courses or in having characteristic topographic expression. Miller, Pine, and Church Creeks follow the sandstone units for some distance, but all three turn abruptly and flow out of the sandstone into the crystalline rocks. In Pine Valley alone is the sandstone continuously represented by a valley. Most of the sandstone areas cross ridge and valley alike, with little if any topographic expression, often not even a break in slope marks the contact between the sandstone and the older crystalline rocks.

Except for the general tendency of the Santa Lucia plutonics to occupy the crest areas in the west, neither of the old crystalline formations show any characteristic topographic expression.

Nor is topography much help in tracing faults. A few minor creeks follow fault lines, and saddles occasionally mark the trace of a fault zone, but in general the faults cut ridge and valley alike, and they may as well follow ridge slopes or crests as valleys.

Tularcitos Area

A second physiographic type is represented in the Tularcitos block, the southwest half of the northeast half of the quadrangle. Here the

topography is more subdued and, with the exception of Tularcitos Ridge, more mature than the surface of the area discussed above. The maximum relief is 3000 feet, but in general local relief is less than half this amount. The valleys are wider, the ridges less steep, broader, and more rounded than in the south. There are no waterfalls, few rapids, but many small swampy areas and a few lakes. This is the open, grass-covered, and inhabited part of the quadrangle.

Most of the streams are sluggish and meander across comparatively broad flood plains. Only the master streams, the lower Carmel, Cachagua, and Tularcitos, are permanent, and the last two often disappear in their upper reaches during the dry months. Providing water for cattle is a major problem to the ranchers in this area.

Broad, high stream terraces flank the Carmel and Cachagua Rivers. Between these terraces the streams have built a second lower flood plain. Many of the smaller streams are intrenched in older flood plain materials. Locally the Carmel has cut through the old stream gravels and deeply into the bedrock below. Rejuvenation in relatively recent time is clearly indicated, and an uplift of at least 250 feet is suggested in the northwest corner of the area.

Here again the streams do most of their work during the high-water stage, frequently tearing out roads and bridges and occasionally even small buildings. During the spring of 1941 Tularcitos Creek widened its channel by about 200 feet in some places.

In this area the topography is of more structural significance, still the streams show no relation to structure, with the possible exception of Tularcitos Creek, which for much of its length is believed to follow a fault zone. The minor streams for the most part flow directly across the structural trend.

This region owes its physiographic characteristics to the weak Tertiary sediments which underlie the area. Wherever crystalline rocks occur, as for example on Tularcitos Ridge, the physiographic features are more like those in the Santa Lucia area. The contact between the basement rock and Tertiary sediments is frequently marked by a pronounced break in slope. Some of the faults show topographic expression in this area. The steep northern face of Tularcitos, of Blue Rock Ridge, and of Hennicksons Ridge may represent eroded fault scarps. In other, even in adjacent parts of the area, the topography gives no indication of the presence of faults.

Although no detailed study has been made in this connection, the flat areas in the western part of the area on either side of Jamesburg, and south of Anastasia Canyon, may represent an uplifted erosion surface of low relief, possibly a continuation of that found by Trask (26, p. 173) in the Point Sur quadrangle. The relatively flat crest of Tularcitos Ridge may itself be a remnant of this same surface.

Sierra de Salinas Area

The third of the major physiographic divisions is the Sierra de Salinas belt lying between the Tertiary synclines on the southwest and Salinas Valley to the northeast. This again is a region of considerable relief, the maximum being 3000 feet. It is a region, like the first, of deep, narrow valleys, but the ridges are broader, more rounded, and for the most part not as steep as those in the southwest. The steep

northwest slope of the Sierra de Salinas, however, has the same narrow, sharp ridges that are common in the Santa Lucia mountain area.

Streams are almost all intermittent in this area and dry throughout most of the summer. While most of these are not as yet meandering, there are few steep canyons like those of the southwest, and many of the streams are either at base level or so feeble as to no longer be able to degrade their channels. Chupines Creek, and locally Rana Creek as well, have reached base level and are building narrow flood plains.

The only structure mapped in this area is that of the Sur metamorphics. The streams flow almost at right angles to the northwestward trend of these folds.

The steep east face of the ridge, rising as it does abruptly from Salinas Valley, suggests an eroded fault scarp. The crest line of the Sierra de Salinas, while much dissected, strongly suggests an erosion surface of low to moderate relief, and the long spurs extending to the southwest, which are relatively flat and even-topped, may be remnants of this same surface. The whole belt, physiographically, has the appearance of a fault block tilted to the southwest.

Salinas Valley Area

The fourth physiographic area within the limits of the Jamesburg quadrangle is a small part of the western margin of Salinas Valley which occupies the northeastern corner of the map. This area is covered by broad alluvial fans which continue to the northeast into the valley proper. No detailed study was made in this region.

GEOLOGIC HISTORY

The earliest event recorded in the Jamesburg quadrangle is the deposition of a great thickness of sediments, predominantly sandy, but containing shales and a few limestone lenses. There is a suggestion that these sediments may have been derived from the north and east. Some time after the deposition of the sedimentary series there was igneous activity, chiefly in the southern part of the area, which resulted in the intrusion of basic sills and dikes. The entire region then suffered metamorphism, probably of the load type, and during this or a later time the series was folded into broad open folds. There may have been some faulting at this time. No date can be set for these events.

At a later time the region was intruded by a batholithic mass of granitic rock. The main intrusions were preceded by small basic plugs and possibly dikes as well. The acid rocks probably entered as a series of small bodies rather than as a large continuous mass. Granite, granodiorite, quartz diorite, and diorite were all emplaced at this time. Small dikes, chiefly aplites, but some pegmatites and aschistic granites and diorites, invaded the metamorphics. Locally injection gneisses were formed and some thermal and pneumatolytic metamorphism affected the country rocks. The intrusions, according to Taliaferro (41, p. 123), are known to have taken place before the Upper Jurassic and the basement complex of metamorphic and igneous rock "may be lower Paleozoic or pre-Cambrian or both."

Uplift followed by erosion, which resulted in the stripping of much of the roof of the batholith, preceded the Upper Jurassic at which time

the Franciscan sediments, the oldest unmetamorphosed rocks in the central California Coast Ranges, were deposited. Within the Jamesburg quadrangle there is no record of the Mesozoic save serpentinized ultrabasic intrusives. The complex late Mesozoic history of the Santa Lucia Mountains is outlined by Taliaferro (41, pp. 123-135).

Since there are no lower Eocene sediments, nothing is known regarding this interval of time, but the area was probably above sea level.

During the middle Eocene, seas again invaded the region and sandstone was deposited. Since this sandstone, found only at one locality, is the sole record of Tertiary sedimentation prior to the Miocene, most of the area may have remained above the sea throughout the Eocene and Oligocene.

The removal of the Mesozoic sediments, and any early Tertiary formations which may have been present, continued into the early lower Miocene in the Jamesburg quadrangle. During upper Vaqueros time the region was again submerged. The Miocene sea advanced over a region of considerable relief. More or less isolated troughs and occasional islands characterized the Vaqueros-Temblor seas in the Jamesburg area and varied conditions of deposition resulted in a great variety of sediments. Rapid deposition, shallow seas, and fairly rugged topography in the surrounding land areas are indicated by the nature of most of these deposits. In the south, some of the sediments may have accumulated on land. Volcanic activity during and possibly preceding this period occurred locally in the Jamesburg area. Andesitic lavas and fragmental rocks accumulated in the Madrona Canyon area. Although throughout most of the Jamesburg area deposition was continuous into the upper Miocene, there is evidence of minor local uplift and erosion during the middle Miocene, between lithologic units which have been separately mapped. This local disconformity may be related to minor movements within the sedimentary basins, a common occurrence in the upper Miocene (Taliaferro 41, p. 140).

The central Tularcitos trough continued to subside during the Monterey sedimentation, and the shales overlapped the older sediments, and were locally deposited directly on the pre-Jurassic basement complex. While the Monterey seas were more extensive in the central area, the lack of any Miocene sediment to the south suggests that the younger sea may have been confined to the Tularcitos trough in contrast to the Vaqueros-Temblor sea which covered much of the southern half of the quadrangle as well. It is possible, of course, that the Monterey sediments have been completely stripped from the southern area.

During Monterey time the surrounding land area must have been relatively low, for throughout the western and central parts of the Tularcitos trough the predominant sedimentation was organic and chemical. To the east, where clastic sediments are more common, the adjacent land may have been somewhat higher. Volcanic activity during this time, as evidenced by tuffaceous material in the shales and a tuff bed near the top of the formation, may have originated beyond the limits of the quadrangle, possibly in the Pinnacles area several miles northeast of Soledad.

Deposition appears to have been continuous into the upper Miocene, but the presence of Monterey debris in the San Pablo sandstone near

the southeast end of Tularcitos Ridge indicates that at least locally a disconformity is present within the upper Miocene.

The San Pablo sea was probably restricted in the Jamesburg quadrangle since the formation has not been found outside the Tularcitos area. The surrounding land must have stood relatively high to supply the coarse debris found locally in these sediments.

There is no record of the Pliocene within the area mapped, but sediments of this age are reported in nearby areas and Pliocene sediments may have been present in the Jamesburg quadrangle, having since been removed by erosion. In some parts of the Santa Lucia Range orogenic movements occurred between the Miocene and Pliocene, whereas in other regions deposition was continuous between these two periods (Taliaferro 41, p. 144).

In the Jamesburg area the major deformation, which may have been initiated in middle Miocene time, reached its climax in the late Pliocene. The northwest structural trend of both the folds and major faults formed at this time parallels and may, in part at least, have been determined by the older Sur structures. The southern crystalline areas may have responded by faulting to the same forces which folded the Tertiary sediments in the north. Elongate blocks of sandstone were faulted down into the older rocks in the Santa Lucia belt while the sediments in the Tularcitos area were being folded and faulted. Contemporaneous in part, but to some extent later than this major orogeny, was the movement which led to the origin of a series of cross-faults throughout the area.

During the period of erosion which followed, a surface of low relief was formed locally within the map area and in surrounding areas as well (Trask 26, p. 173). In the mid-Pleistocene (Taliaferro 41, p. 148) uplift and a renewal of faulting rejuvenated the streams, resulting in dissection of the former erosion surface to the sub-mature stage in which we see it today.

A still more recent uplift has caused some of the streams to cut below their former base levels and leave broad stream terraces.

ECONOMIC GEOLOGY

While there are no mineral deposits being exploited in the Jamesburg quadrangle at the present time there are evidences of a few small-scale activities in the past and some interesting features which invite future prospecting.

On the south side of Tularcitos Ridge in Trampa Canyon approximately 1,000 feet north of the ranch house, copper was once mined from a mineralized zone in the Sur marble lens near its contact with the Santa Lucia quartz diorite. The copper occurs as chalcopyrite and is intimately associated with pyrite. Apparently the ore was not rich enough to make mining profitable and the enterprise was abandoned about 1931.

On the north branch of the Little Sur River an old cabin and claim-markers attest to a gold prospect. The prospect has been abandoned, the tunnels blown up by ranchers. It appears that the claim was located in a quartz-rich pegmatite which outcrops on the valley wall north of the cabin. No ore nor mineralized rock was found at this locality.

On the south slope of Long Ridge near the western margin of the map are several abandoned shafts of an old quicksilver mine. The mineralization occurs in a shattered silica-carbonate rock within the Blue Rock fault zone. The mine was abandoned prior to 1937 and nearby residents could offer little information about it.

An old drift, now almost completely slumped, on Red Rock Hill north of Madrona Canyon marks what may have been a mercury prospect; however there is no evidence of mineralization in the lavas in this area.

Reports of a graphite claim on the road to Tassajara Hot Springs about 3½ miles south of Chews Ridge lookout station were not verified by the writer.

Lime made from the limestone deposit (NE¼ sec. 29, T. 19 S., R. 4 E., M.D.) in Lime Canyon, less than 3 miles from Tassajara Hot Springs, was used in mortar for construction of the sandstone hotel at the Springs. (See figure 16.)*

The presence of small amounts of chromite in the serpentine plugs has already been noted, and although it was nowhere seen in sufficient abundance to warrant development the possibility of commercial chromite in these areas has not been precluded by this investigation.

Probably the most interesting possibility for economic mineralization in the quadrangle is at the contacts of the Sur marbles with the Santa Lucia intrusives. Skarns, contact-metamorphic mineral zones, also known as tactite, are occasionally developed along these contacts. While the larger marble lenses are limited in number and concentrated chiefly in the southern part of the area, small marble lenses are occasionally encountered throughout the Sur terrain. With the exception of the Trampa Canyon area, already referred to, the writer did not discover any highly mineralized marbles but there is reason to believe that such may be found within the limits of the quadrangle. A piece of high-grade scheelite float, reportedly found in the region of the headwaters of the Carmel River, is suggestive in this connection.

The nature of the coarse pegmatites in the Santa Lucia area suggests the possibility of finding commercial feldspar or mica in this area.

While the quartz veins are usually barren, pyrite is not uncommon and the writer was shown several pieces of float containing minor traces of gold which were reportedly found in the Sierra de Salinas area near the eastern margin of the map.

Traces of molybdenite are occasionally present in the granitized rocks in the Sur-Santa Lucia contact zone and lend some support to the rumors of such deposits in this area.

The oil companies have done reconnaissance work in the sedimentary area, but so far as is known have neither acquired leases nor done any exploratory drilling. The geologic conditions are not, on the whole, favorable for the presence of petroleum in this area. The Monterey formation which is a source rock in many California fields, is rarely bituminous and suitable reservoir strata and trap structures are not apparent.

In the adjoining Monterey quadrangle, 1 mile northwest of the corner of the Jamesburg quadrangle, is a thin bed of phosphate rock

* Mrs. Helen G. Holohan, personal communication.

(phosphorite), composed of collophane.* In one exposure, this bed is about one foot thick, while in another it is about 6 inches. The rock is brown oölitic (very fine-grained), and inter-bedded with white diatomaceous and foraminiferal Monterey shale. It is quite possible that this rock may occur in the Jamesburg quadrangle, though no exposure has been reported.

Within the Jamesburg quadrangle, one mile southeast of Rancho del Monte, is an adobe plant, where sun-dried adobe bricks are made from the surface soil of a terrace deposit, by the Carmel Building Specialties Company.

BIBLIOGRAPHY

Beal, Carl

15 Geology of the Monterey quadrangle, California: unpublished M.A. Thesis, Department of Geology, Stanford University, 1915.

Becker, G. F.

88 Quicksilver deposits of the Pacific slope: U. S. Geol. Survey Mon. 13, 486 pp., 1888.

Galliher, E. Wayne

31 Collophane from Miocene brown shales of California: Am. Assoc. Petroleum Geologists Bull., vol. 15, pp. 257-269, 1931 (phosphatic concretions from Carmel Valley, p. 266).

Herold, C. L.

35 Geology of the Salinas quadrangle: unpublished M.A. Thesis, Department of Geological Sciences, University of California.

36 Distribution of Eocene rocks in Santa Lucia Mountains, California: Am. Assoc. Petroleum Geologists Bull., vol. 20, pp. 491-494, 1936.

37 Further evidence for age of volcanism, Pinnacles National Monument, California: Am. Assoc. Petroleum Geologists Bull., vol. 21, pp. 1341-1344, 1937.

39 Geology of the Salinas and the Jamesburg quadrangles, California (abstract): Geol. Soc. America Bull. 50, p. 1951, 1939.

Jenkins, Olaf P.

37 Source data of the geologic map of California: California Div. Mines Rept. 33, pp. 9-37, 1937.

Lawson, Andrew C.

93 The geology of Carmelo Bay: Univ. California, Dept. Geol. Sci. Bull., vol. 1, pp. 1-59, 1893.

Reed, Ralph D.

26 Miocene paleogeography of the central Coast Ranges of California: Am. Assoc. Petroleum Geologists Bull., vol. 10, pp. 130-137, 1926.

33 Geology of California. Am. Assoc. Petroleum Geologists, 335 pp., 1933.

Reiche, Parry

37 Geology of the Lucia quadrangle, Calif.: Univ. California, Dept. Geol. Sci. Bull., vol. 24, pp. 115-168, 1937.

---

* Galliher, E. Wayne, *Collophane from Miocene brown shales of California:* Am. Assoc. Petroleum Geologists Bull., vol. 15, p. 266, 1931:

"The Monterey shale exposed in Carmel Valley approximately 15 miles from Carmel, California, contains a bed of these phosphatic concretions. This bed, approximately 8 inches thick and persistent for at least 65 feet, is a solid mass of ovoid grains less than a millimeter in maximum diameter, which are loosely cemented together with limonite."

See also Austin F. Rogers and Paul F. Kerr, *Optical Mineralogy,* 2d ed., McGraw-Hill Book Company, Inc., 1942, pp. 226-228.

Rumbley, Jane

30 Geologic map of the north half of the Jamesburg quadrangle. Department of Geology, Stanford University, 1930. Unpublished.

Schombel, L. F.

40 Preliminary report on the geology of the Soledad quadrangle, California. Unpublished M.A. Thesis, Department of Geological Sciences, University of California, 1940.

Smith, J. P.

16 The geologic formations of California: California Min. Bur. Bull. 72, 47 pp., 1916.

Taliaferro, N. L.

33 The relation of volcanism to diatomaceous and associated siliceous sediments: Univ. California, Dept. Geol. Sci. Bull., vol. 23, pp. 1-56, 1933.

43 Geologic history and structure of central California Coast Ranges: California Div. Mines Bull. 118, pp. 119-163, 1943.

Trask, Parker D.

26 Geology of the Point Sur quadrangle, Calif.: Univ. California, Dept. Geol. Sci. Bull., vol. 16, pp. 119-186, 1926.

Waring, Gerald A.

15 Springs of California: U. S. Geol. Survey Water-Supply Paper 338, 410 pp., 1915 (Tassajara Hot Springs, pp. 57-60).

MINERAL EXHIBIT AND STATISTICS

MINERAL STATISTICS FOR 1943

By Henry H. Symons *

OUTLINE OF REPORT

INTRODUCTION

The counties of California have produced for some years past more than 50 different mineral substances, the total value of which was estimated at $419,536,000 for the year 1943. (See *California Journal of Mines and Geology* for January 1944.)

At present, reports for most of the producers are at hand. Substances for which complete data are now compiled are summarized in this report. There was no recorded commercial production during 1943 of antimony, bismuth, calcium silicate, fluorspar, graphite, marble, mica, nickel, onyx and travertine, serpentine, shale oil, or tin. There was a single producer each of coal, lithia, mineral paint, potash, pyrite, slate, and titanium.

BORATES

During 1943 there was produced in California a total of 249,523 net tons of borate, as compared with 232,833 tons in 1942. The material shipped during 1943 included the sodium borates, kernite (rasorite), kramerite, from Kern County; crystalline borax prepared by evaporation of brines at Searles Lake in San Bernardino County and Owens Lake in Inyo County; and a small amount of colemanite from Death Valley, Inyo County.

Because the crude ore is not sold as such, but is almost entirely refined into borax of commerce before shipping, and because the crude ore varies widely in boric acid content, the tonnage has been recalculated on the basis of 40 percent A.B.A. This is approximately the average A.B.A. content of colemanite after calcining, and also of the crystallized borax obtained from evaporation of the lake brines.

The 1943 output totaled 216,687 net tons, valued at $4,953,174, as compared with 203,716 tons worth $4,929,553 for the year 1942. This

* Statistician and Curator, Division of Mines. Manuscript submitted for publication July 18, 1944.

production was from two properties each in Inyo and San Bernardino Counties, and one in Kern County.

CARBON-DIOXIDE GAS

Carbon dioxide produced in California during 1943 came from wells operated by two companies near Niland, Imperial County, and by one company near Hopland, Mendocino County. A total of 227,424 M. cu. ft. of carbon-dioxide gas was compressed to make 14,037 net tons of dry ice, valued at $248,126, as compared with 193,143 M. cu. ft. of gas which made 11,921 tons of dry ice, worth $310,000 in 1942.

CEMENT

During 1943 the production of cement in California totaled 18,515,085 barrels, valued at $27,865,466 f.o.b. plant, of which 9,848,719 barrels, worth $14,971,871, came from mills in northern California and 8,666,366 barrels, worth $12,893,595, came from mills in southern California. The 1943 output was a decrease in both amount and value from that of 1942 which was the largest annual yield of cement ever recorded in the State and amounted to 23,306,578 barrels, worth $35,808,841.

Shipments of cement during 1943 were made by twelve plants in eleven counties to the extent of 17,804,421 barrels, valued at $27,500,347 f.o.b. plant, as compared with 23,732,414 barrels, worth $36,964,122, in 1942. During the year there were seven mills in northern California; one each in Calaveras, Contra Costa, Merced, San Benito, San Mateo, Santa Clara, and Santa Cruz Counties, which shipped a total of 9,548,888 barrels, valued at $15,216,224; and five mills in southern California; two in San Bernardino County, and one each in Kern, Los Angeles, and Riverside Counties, which shipped a total of 8,255,533 barrels, valued at $12,284,123. There was an average of 2,725 men employed in the above mills during the year. The mill in San Benito County discontinued operation during the year. The annual capacity of California cement mills according to the U. S. Bureau of Mines, was 27,690,000 barrels as of January 1944, as compared with 27,540,000 barrels for January 1943.

DOLOMITE

The 1943 output of dolomite in California totaled 331,251 net tons, valued at $472,756 and came from two properties in Monterey County and one each in Los Angeles, San Benito, and Tuolumne Counties. The 1943 production was the largest annual yield on record in this State. The 1942 production amounted to 142,552 tons, worth $413,469.

The material shipped during the year was utilized for magnesium metal, for steel furnace flux and refractories, stucco dash, terrazzo, kalsomine, poultry grit, artstone, in mineral-wool, for the manufacture of carbon dioxide, and for lime.

GYPSUM

Shipments of gypsum in California during 1943 amounted to 495,967 net tons, worth $916,883, and came from five properties in Kern County and one property each in Imperial, Riverside, and Ventura Counties. In 1942, production was 425,268 tons, worth $791,892. In

addition to the 1943 production shown above, a considerable amount of gypsum was obtained in Alameda County from a chemical process for reducing magnesium salts from salt-works bittern water with lime. This production was not included in the 1943 figures because it was used with lime and magnesite. The 1943 figures show the largest annual output ever reported in the State. This was used in the manufacture of hardwall and other plasters, in cement, and for agricultural purposes. Tonnage used in the agricultural field now exceeds that for industrial and structural plasters and in cement.

IRON

Iron ore shipments in California during 1943 totaled 907,458 net tons, valued at $2,341,827 f.o.b. mine, and came from four properties in San Bernardino County and one property each in Santa Cruz and Shasta Counties. This was the largest annual production of iron ore ever reported in this State, being greater than the total of all iron mined from 1881 to date. It shows a marked increase over the 1942 yield, which was 99,092 net tons, worth $371,562. The ore mined during 1943 was hematite from San Bernardino County, which went to the new steel plant at Fontana, and in part was used in the manufacture of high-iron cement; and magnetite from Shasta County and magnetite sand from Santa Cruz County, both used as aggregate in heavy concrete for ballast.

"INDUSTRIAL" LIMESTONE

''Industrial'' limestone was shipped from 19 properties in 11 counties of California during 1943, and totaled 495,262 net tons, valued at $1,378,647. The 1942 output came from 22 properties in 12 counties and totaled 474,764 tons, worth $1,155,352.

1943 "Industrial" Limestone Production by Counties

County	Amount net tons	Value
San Bernardino	50,614	$142,099
Santa Clara	161,003	258,502
Santa Cruz	24,372	156,703
El Dorado, Inyo, Los Angeles, Riverside, San Mateo, Tuolumne, Ventura*	259,273	821,343
Totals	495,262	$1,378,647

Included in the above figures are 172,664 tons of limestone used in the making of 86,332 net tons of lime valued at $922,800. This production came from two properties in San Bernardino County, and one property each in Alameda, El Dorado, Santa Cruz, and Tuolumne Counties. Also included are 161,752 tons of limestone valued at $429,852, used for agricultural purposes and in poultry grit, stock feed, and as a filler in fertilizers. In 1942 there were 197,096 tons of limestone burned to make 98,548 tons of lime, worth $961,803.

The above production figures do not include limestone used in the manufacture of cement, macadam, or concrete. They do, however, include limestone burned for lime; limestone used as smelter and foundry flux, in glass and sugar making, and in other special chemical and manufacturing processes; limestone used for fertilizer (agricultural

* Combined to conceal production of single operators in each county.

"lime"), "roofing gravel," paint and concrete filler, whiting for paint, putty, kalsomine, terrazzo, paving dust, chicken grit, stock feed, carbon-dioxide gas, oil wells, mineral wool, "paving compound," facing dust for concrete pipe, also for rubber and magnesite mix.

The limestone production for 1943 was made by four companies in San Bernardino County; three each in Santa Clara and Santa Cruz Counties; two each in El Dorado and Tuolumne Counties; and one each in Inyo, Los Angeles, Riverside, San Mateo, and Ventura Counties. The material from San Mateo County and part from Santa Clara County was shells, dredged from San Francisco Bay, which were ground and used for agricultural purposes, chemical purposes, and for poultry grit.

MAGNESIUM SALTS

Magnesium salts were produced in California during 1943 by two companies in San Mateo County, and one each in Alameda and San Diego Counties, with a total of 9,026 net tons, valued at $728,065; compared with 6,260 tons, worth $642,680 in 1942. The material from Alameda County was basic magnesium carbonate and magnesium hydroxide; that from San Diego County was magnesium chloride; and that from San Mateo County was basic magnesium carbonate, magnesium carbonate, magnesium hydroxide, and magnesium oxide. Also coming from Alameda County, but not included in the above totals, was a tonnage of magnesium hydroxide used as magnesite. The 1943 output was the largest annual production in both amount and value thus far reported in this State.

NATURAL GAS

During 1943 there were 443,219,847 M. cu. ft. of natural gas, worth $28,046,729, produced and utilized in California, compared with 413,180,942 M. cu. ft., worth $25,698,052, in 1942. The following table gives the distribution by counties of natural gas utilized in 1943:

County	*M. cu. ft.*	*Value*
Fresno	48,944,169	$2,793,749
Kern	65,576,727	3,395,175
Kings	67,277,904	3,035,350
Los Angeles	54,480,234	3,894,849
Orange	15,705,073	1,079,728
Sacramento	62,766,484	4,767,138
San Joaquin	12,446,567	888,205
Santa Barbara	4,052,577	298,960
Solano	56,605,382	4,780,407
Ventura	43,133,041	2,247,380
Contra Costa, Humboldt, Madera, Mendocino, Stanislaus, Sutter, Tulare, Yolo *	12,331,689	865,788
Totals	443,219,847	$28,046,729

Natural gas gasoline produced during 1943 was reported from all fields by 84 plants; a total of 528,771,009 gallons, valued at $21,968,165, as compared with 415,624,450 gallons, valued at $22,374,692, from 87 plants in 1942. In 1943 there was also a total of 90,723,022 gallons of liquefied petroleum gas, valued at $2,238,954, as compared with 68,930,472 as reported in 1942.

* Combined to conceal outputs of individual operators in each.

PETROLEUM

The crude petroleum produced in California during 1943 amounted to 284,145,702 barrels, valued at $289,323,406 at the well. This was an increase in both amount and value as compared with the 1942 totals which were 247,491,289 barrels, worth $242,481,545. The totals of quantity are compiled from monthly reports filed by operators with the State Oil and Gas Supervisor.

The following table gives the comparison of the 1942 output with that of 1943, by counties:

	1942		*1943*	
County	*Barrels*	*Value*	*Barrels*	*Value*
Fresno	23,595,303	$21,206,580	37,869,219	$37,779,881
Kern	72,093,741	64,477,255	84,934,943	86,174,973
Kings	8,906,011	11,131,160	10,326,575	12,907,422
Los Angeles	87,248,536	90,620,837	87,983,756	90,193,521
Orange	24,122,716	25,459,382	26,441,558	26,325,466
Santa Barbara	13,267,311	9,407,096	16,285,344	13,523,527
Ventura	17,853,644	20,148,305	20,279,921	22,400,750
Other counties *	39,027	30,930	24,386	17,866
Totals	247,491,289	$242,481,545	284,145,702	$289,323,406

It will be noted in the above table that all major petroleum producing counties showed an increase in amount in 1943 as compared with 1942, and that Los Angeles County was the only one showing a decreased value in output, this being due to the increased production of heavier crudes as compared with those of lighter gravity.

QUICKSILVER

The production of quicksilver in California during 1943 totaled 33,948 flasks, valued at $6,177,159 f.o.b. mine, from 86 mines in 17 counties; as compared with 30,087 flasks, worth $5,553,357 in 1942, from 101 properties in 18 counties. The 1943 output was distributed as follows:

County	*Flasks 76 lbs.*	*Value*
Fresno	32	$5,930
Lake	4,206	774,813
Napa	2,023	363,017
San Luis Obispo	2,625	478,442
Santa Clara	1,736	322,871
Sonoma	4,121	761,654
Colusa, Contra Costa, Del Norte, Inyo, Kings, Monterey, San Benito, Santa Barbara, Siskiyou, Trinity, Yolo†	19,205	3,470,432
Totals	33,948	$6,177,159

The 1943 output of quicksilver had the highest annual value recorded in the past 93 years in California, and was the largest in amount since 1883. The California production was the largest of any State in the United States and was approximately 63 percent of the national yield.

* Include San Bernardino, San Luis Obispo, Santa Clara, and Tulare Counties.
† Combined to conceal production of individual operators in each.

During 1943 the average New York quotation of quicksilver was \$195.21 per 76-pound flask, while the average price received by the California miner was \$181.96 per 76-pound flask; as compared with the 1942 New York average quotation of \$196.35 per 76-pound flask, and the average price received by California miners of \$184.58 per 76-pound flask.

SALT

The 1943 salt production in California totaled 631,776 net tons, valued at \$1,695,231, and came from three properties in Alameda County; two in San Bernardino County; and one each in Kern, Los Angeles, Monterey, and San Diego Counties. The production for 1942 was 672,324 tons, worth \$1,922,991. In 1943 two properties each in Imperial and San Bernardino Counties, and one property each in Modoc and Orange Counties, which made a production in 1942, were closed down owing to floods or manpower shortage.

The average value reported by salt producers in California in 1943 was \$2.68 per net ton, f.o.b. plant compared with \$2.90 in 1942; \$2.72 in 1941; \$2.79 in 1940; \$2.75 in 1939; \$2.78 in 1938; \$2.82 in 1937; and \$3.08 in 1936.

Most of the salt produced in California is obtained by evaporation of water of the Pacific Ocean, plants being located on the shores of San Francisco, Monterey, and San Diego bays, and at Long Beach. Additional amounts (in part, rock salt), are derived from lakes and lake beds in the desert regions, mainly in Imperial, Kern and San Bernardino Counties, and evaporation of alkaline lake water in Modoc County. A small amount of valuable medicinal salts has been obtained by evaporation of the water of Lake Mono, Mono County, and from a mineral spring in Butte County.

SILICA

The output of silica (quartz and glass sand) in California during 1943 amounted to 161,318 net tons, valued at \$533,434 f.o.b. rail shipping point, and came from three properties in San Bernardino County, and one each in Contra Costa, Los Angeles, Mariposa, Monterey, Orange, Riverside, and Stanislaus Counties. The above figures were a decrease in both amount and value as compared with those of 1942 (193,174 tons, worth \$692,762), the largest annual recorded output of these materials in this State.

Of the 1943 production, 56,346 tons, worth \$149,873, was quartz, and/or ganister and came from properties in Mariposa, Los Angeles, San Bernardino, and Stanislaus Counties; the remaining 104,972 tons, worth \$383,561, was glass sand and came from Contra Costa, Monterey, Orange, and Riverside Counties.

These materials were combined because of an overlapping in their uses and specifications as to the silicon dioxide (SiO_2) content. Vein quartz, ganister, and silica sand are used as refractories, in fire brick, in ceramic mixes and glazes, and as abrasives. It is possible to use quartz as well as glass sand in the manufacture of glass; also, some of the quartz was used in the manufacture of ferrosilicon.

Not included under this heading are such forms of silica as sandstone, flint, tripoli, diatomaceous earth, and the gem forms of rock crystal, amethyst, and opal.

SOAPSTONE AND TALC

The total production of talc and soapstone in California during 1943 amounted to 63,012 net tons, valued at $743,056; compared with 47,782 tons, worth $545,509, in 1942. The 1943 output was the largest annual production ever reported in this State, and was 62,280 tons of high-grade talc coming from six properties in Inyo County and four properties in San Bernardino County; and 732 tons of soapstone from a property each in Amador, and El Dorado Counties. The talc was used in ceramics, as a filler in paint, cloth, and paper, in cosmetics, medicines, and rubber.

ACCESSIONS TO THE EXHIBIT

By Henry H. Symons *

The museum of the State Division of Mines possesses an exceptionally fine collection of rocks and minerals of economic and academic value. It ranks among the first five such collections in North America and contains not only specimens of most of the known minerals found in California, but much valuable and interesting material from other States and foreign countries as well.

The exhibit is daily visited by engineers, students, business men and prospectors as well as tourists and sightseers. In addition to its practical use in the economic development of California's mineral resources, the collection is a most valuable educational asset to the State and to San Francisco.

Mineral specimens suitable for exhibit purposes are solicited, and their donation will be appreciated by the Division of Mines, as well as by those who utilize the facilities of the collection.

Among the specimens received recently and catalogued for the exhibit are the following:

21150 KRAMERITE (hydrous sodium-calcium borate). Radiating prismatic crystal groups. Donor: Peter Graham, Pacific Coast Borax Company, February 1944. In case 149.

21151 TINCAL (borax, $Na_2B_4O_7.10H_2O$). Pseudomorphic after rasorite. From north end of orebody, Borax mine. Donor: Peter Graham, Pacific Coast Borax Company, February 1944. In case 149.

21152 DUMORTIERITE. From Rochester, Nevada. Donor: J. Cunningham, February 1944. In case 241.

21153 LAZULITE (aluminum-iron-magnesium phosphate). From White Mountains, Mono County. Donor: J. A. Meyers, Champion Sillimanite Company. In case 143.

21154 PECTOLITE, 'stinging' (calcium-sodium basic silicate, $HNaCa_2(SiO_3)_3$). From Vandermade quarry, Prospect Park, New Jersey. Donor: T. Orchard Lisle, February 10, 1944. In case 126.

21155 DATOLITE (basic calcium borosilicate, $HCaBSiO_5$). Well crystallized. Donor: T. Orchard Lisle, February 10, 1944. In case 132.

21156 ZIRCON and CORUNDUM. From Ankie Field, Queensland, Australia. Donor: William A. Wacker, February 1944. In case 703.

* Statistician and Curator, Division of Mines. Manuscript submitted for publication July 18, 1944.

LABORATORY

CORRECTIONS AND ADDITIONS TO BULLETIN 113

By George L. Gary *

No. 133 Anauxite, a hydrous aluminum silicate $Al_2O_3.3SiO_2.2H_2O$, occurs in small tabular crystals in andesite, near San Andreas, Calaveras County.

No. 134 Pyrophyllite, a hydrous aluminum silicate $H_2Al_2Si_4O_{12}$, occurs in radiating masses near Jamestown, Tuolumne County.

No. 135 Analcime, a hydrous sodium and aluminum silicate, $NaAlSi_2O_6.H_2O$, has been reported from the Harvard mine near Jamestown, Tuolumne County.

---

* Mineral Technologist, Division of Mines. Manuscript submitted for publication April 17, 1944.

LIBRARY

LIBRARY REPORT

By James M. Little *

OUTLINE OF REPORT

INTRODUCTION

The library of the Division of Mines contains more than 6,000 selected volumes on mines, mining, and allied subjects. It is also the repository for reports and bulletins of technical departments of Federal and State governments and educational institutions both domestic and foreign. Current copies of newspapers published in the mining centers of the State are also available for reference.

The library and reading room are open to the public during the usual office hours, when the librarian may be freely called upon for all necessary assistance.

PUBLICATIONS OF THE UNITED STATES GEOLOGICAL SURVEY AND UNITED STATES BUREAU OF MINES

The library of the Division of Mines has available for public reference the following publications of the United States Geological Survey: Annual Reports, Monographs, Professional Papers, Bulletins, Water-Supply Papers, Mineral Resources, Folios of the Geologic Atlas of the United States (broken file), Maps with Descriptive Text (broken file), Administrative Publications (broken file); and the following publications of the United States Bureau of Mines: Bulletins, Technical Papers, Economic Papers (broken file), Mineral Resources of the United States, Monographs (broken file), Reports of Investigations, Information Circulars.

Reports, mainly on California, recently received from the Survey and Bureau of Mines include:

United States Geological Survey

Bulletins

937—Part 1. Bibliography of North American Geology, 1929-1939.

937—Part 2. Index to Part 1.

* Librarian, Division of Mines.

7—36585

United States Bureau of Mines

Technical Papers

657 Dilution of Stack Effluents.
658 Production of Industrial Explosives in the United States for 1942.
660 Coke-oven Accidents in the United States for 1942.
661 Electrical Devices Applied to Metallurgical Research.

Miners' Circular

44 Construction, Care, and Use of Permissible Flame Safety Lamps.

Reports of Investigations

Nos. 3749; 3750; 3751; 3752; 3753; 3755; 3756; 3758.

Information Circulars

Nos. 7276; 7277; 7278; 7279; 7280; 7281; 7282; 7283; 7284; 7285.

PUBLICATIONS OF STATE SURVEYS

A broken file of mining and geological publications, issued by the organizations listed below, may be consulted in the library of the Division of Mines.

State of California

Department of Public Works, Division of Water Resources

Report on Kennett Power System of Central Valley Project, June 1935.

Report on Water Supplies from Rector and Conn Creeks in Napa County, August 1940.

Electric Power Features of the State Water Plan in the Great Central Valley Basin of California, August 1941.

Bulletin No. 39-I, South Coastal Basin Investigation, Records of Ground Water Levels at Wells for the Year 1940—Precipitation Records for the Season 1939-40, September 1941.

Bulletin No. 21-M, Report on Irrigation Districts in California for the Year 1941.

Auxiliary Electric Power Facilities Required for General Valley Project, January 1942.

Report on Jenner Jetty at Mouth of Russian River, April 1942.

Report of Sacramento-San Joaquin Water Supervision for Year 1941, June 1942.

Magnitude, Stage and Frequency of Flood Flows of Sacramento River near Rio Vista, December 1942.

Report of Sacramento-San Joaquin Water Supervision for Year 1942, June 1943.

Flood Flows and Stages in Sacramento and Lower San Joaquin Valleys, 1934-1942, September 1943.

Bulletin 1, Publicly Operated Electric Utilities in Northern California, 1941.

Bulletin 50, Use of Water by Native Vegetation, 1942.

Water Code, Chapter 368, Statutes of 1943.

Rules and Regulations Governing the Determination of Rights to the Use of Water, 1937.

Rules. Regulations and Information Pertaining to Appropriation of Water in California, 1941.

Divisions 1, 2, and 4 of Water Code, Chapter 368, Statutes of 1943, Water Rights.

Division 3 of Water Code, Chapter 368, Statutes of 1943, Supervision of Dams.

Division 6 of Water Code, Chapter 368, Statutes of 1943, State Water Plan.

California Cooperative Snow Surveys, Snow Surveys and Precipitation Data and Forecasts of Stream Flow, April 10, 1944.

California Cooperative Snow Surveys, Snow Surveys and Precipitation Data and Forecasts of Stream Flow, May 10, 1944.

Maps, Central Valley Project.

Other States

Alabama Geological Survey, University.
Alaska (Territorial Commissioner of Mines), Juneau.
Arizona Bureau of Mines, Tucson.
Arkansas Geological Survey, Little Rock.
Colorado Bureau of Mines, Denver.
Connecticut Geological and Natural History Survey, Hartford.
Florida Department of Conservation, Tallahassee.
Georgia Division of Geology, Atlanta.
Idaho Bureau of Mines and Geology, Moscow.
Idaho Inspector of Mines, Boise.
Illinois Geological Survey, Urbana.
Indiana Division of Geology, Indianapolis.
Iowa Geological Survey, Des Moines.
State Geological Survey of Kansas, Lawrence.
Kentucky Geological Survey, Frankfort.
Louisiana Department of Conservation, New Orleans.
Maine State Geologist, Augusta.
Maryland Geological Survey, Baltimore.
Michigan Geological Survey, Lansing.
Minnesota Geological Survey, Minneapolis.
Mississippi State Geological Survey, University.
Missouri Bureau of Geology and Mines, Rolla.
Montana Bureau of Mines and Geology, Butte.
Nebraska Geological Survey, Lincoln.
Nevada State Bureau of Mines, Reno.
New Jersey Department of Conservation and Development, Trenton.
New Mexico Bureau of Mines and Mineral Resources, Socorro.
New York Science Division, Albany.
North Carolina Geological and Economic Survey, Chapel Hill.
North Dakota Geological Survey, Grand Forks.
Ohio Geological Survey, Columbus.
Oklahoma Geological Survey, Norman.
Oregon State Department of Geology and Mineral Industries, Portland.
Pennsylvania Topographic and Geological Survey, Harrisburg.
South Dakota State Geological Survey, Vermillion.
Tennessee Division of Geology, Nashville.
Texas Bureau of Economic Geology, Austin.
Virginia Geological Survey, University.
Washington State Department of Conservation and Development, Pullman.
West Virginia Geological Survey, Morgantown.
Wisconsin Geological and Natural History Survey, Madison.
Wyoming Geological Survey, Cheyenne.

PUBLICATIONS OF FOREIGN GOVERNMENTS

Publications of the following departments of foreign governments are received and current issues may be consulted in the library. Earlier issues of foreign-language publications have been loaned to the California Academy of Sciences in Golden Gate Park, because of the limited storage space at the Divisions' offices in the Ferry Building. They may, however, be consulted at the Academy.

Alberta Research Council, Edmonton.
Argentina Direccion General de Minas y Geologica, Buenos Aires.
British Columbia Minister of Mines, Victoria.
British Museum and Natural History, London.
Canada Department of Mines, Ottawa.
Cuerpo de Ingenieros de Minas y Aguas del Peru, Lima.
Direccion General de Minas y Petroleo, Mexico City.
Direction of Mines, Dakar, French West Africa.
Geological Service of Minas Geraes, Bella Horizonte, Brazil.
Geological Survey of Canada, Ottawa.
Geological Survey of Scotland.
Instituto Historica e Geographico Rio de Janeiro.

Museo de Historia Natural de Montevideo, Uruguay.
Museu Nacional, Rio de Janeiro.
New South Wales Department of Mines, Sydney, Australia.
New Zealand Geological Survey Branch, Wellington.
Nova Scotia Department of Public Works and Mines, Halifax.
Ontario Department of Mines, Toronto, Canada.
Quebec Bureau of Mines, Quebec.
Queensland Department of Mines, Brisbane, Australia.
Service of Mines, Brazzaville, French Equatorial Africa.
South Australia Department of Mines, Adelaide.
Transvaal Chamber of Mines, Johannesburg, South Africa.
Western Australia Geological Survey, Perth.

PUBLICATIONS OF FOREIGN AND DOMESTIC SOCIETIES AND EDUCATIONAL INSTITUTIONS

Academia de Ciencias y Artes de Barcelona, Spain.
Academy of Natural Sciences of Philadelphia.
American Association of Petroleum Geologists, Tulsa, Oklahoma.
American Geographical Society of New York.
American Institute of Mining and Metallurgical Engineers, New York.
American Journal of Science, New Haven, Conn.
American Philosophical Society, Philadelphia.
Australian Museum, Sydney.
California Academy of Sciences, San Francisco.
Canadian Institute of Mining and Metallurgy, Montreal.
Carnegie Institution of Washington.
Cleveland Museum of Natural History, Cleveland, Ohio.
Colorado College Publications, Colorado Springs.
Colorado Scientific Society, Denver.
Commonwealth Club, San Francisco.
Economic Geology, Lancaster, Pennsylvania.
Field Museum of Natural History, Chicago.
Franklin Institute of the State of Pennsylvania, Lancaster.
Geological Society of America, Columbia University, New York.
Geological Society of London.
Institution of Mining and Metallurgy, London.
Instituto de Mineralogia y Geologia, Universidad de Tucuman, Argentina.
Instituto Geologico de Mexico, Mexico, D. F.
Journal of Geology, Chicago.
Mineralogical Society of America, Menasha, Wisconsin.
Michigan College of Mining and Technology, Houghton.
Mining and Metallurgical Society of America, New York.
Missouri School of Mines and Metallurgy, Rolla.
National Research Council, Washington, D. C.
New York Academy of Sciences, New York.
New York State Museum, Albany.
Pennsylvania State College, State College.
Philippine Journal of Science, Manila.
Royal Society of South Australia, Adelaide.
Seismological Society of America, Stanford University.
Sierra Club, San Francisco.
Society of Economic Paleontologists and Mineralogists, Fort Worth, Texas.
Southern California Academy of Sciences, Los Angeles.
Stanford University, Palo Alto, California.
University of California Publications in Engineering, Geography, and Geology, Berkeley.
University of California Publications in Geography, Berkeley.
University of California Publications in Geology, Berkeley.
University of Harvard, Department of Mineralogy and Petrography, Cambridge, Mass.

CURRENT MAGAZINES

Current issues of the technical magazines listed below are on file in the reading room of the library, and may be consulted.

Asbestos, Philadelphia, Pennsylvania.
Brick and Clay Record, Chicago.

California Magazine of the Pacific, San Francisco.
California Mining Journal, Auburn.
California Oil World, Los Angeles.
California Safety News, San Francisco.
Canadian Mining Journal, Gardenvale, Quebec.
Chemical and Metallurgical Engineering, New York City.
Chemical Engineering and Mining Review, Melbourne, Australia.
Civil Engineering, New York City.
Colorado School of Mines, Golden, Colorado.
Engineering and Mining Journal, New York City.
Fusion Facts, Whittier, California.
Gold, Toronto, Canada.
Grizzly Bear, Los Angeles.
Hercules Mixer, Wilmington, Delaware.
Independent Monthly, Tulsa, Oklahoma.
Lubrication, The Texas Co., New York City.
Metals and Alloys, Pittsburg, Pennsylvania.
Mining and Contracting Review, Salt Lake City.
Mineralogist, Portland, Oregon.
Mining Congress Journal, Washington, D. C.
Mining and Industrial News, San Francisco.
Mining and Geological Journal, Melbourne, Victoria, Australia.
Mining Journal, London.
Mining Journal, Phoenix, Arizona.
Mining and Metallurgy, New York City.
Mining World, Seattle.
Nickel Steel Topics, New York City.
Northwest Mining News, Spokane, Washington.
Oil and Gas Journal, Tulsa, Oklahoma.
Oil, Paint and Drug Reporter, New York City.
Oil Weekly, Houston, Texas.
Pacific Purchaser, San Francisco.
Petroleum World, Los Angeles.
Queensland Government Mining Journal, Brisbane, Australia.
Rock Products, Chicago.
Rocks and Minerals, Peekskill, New York.
Scientific American, New York City.
Southwest Builder and Contractor, Los Angeles.
Standard Oil Bulletin, San Francisco.
Stone, New York City.
Western Mining News, San Francisco.

NEWSPAPERS

Current issues of the following papers are received and kept on file in the library:

Alaska Weekly, Seattle, Washington.
Amador Dispatch, Jackson, California.
Banner, Sonora, California.
Barstow Printer, Barstow, California.
Bridgeport Chronicle-Union, Bridgeport, California.
Calaveras Californian, Angels Camp, California.
Calaveras Prospect, San Andreas, California.
Daily Commercial News, San Francisco, California.
Del Norte Triplicate, Crescent City, California.
Denver Mining Record, Denver, Colorado.
Inyo Independent, Independence, California.
Inyo Register, Bishop, California.
Las Vegas Age, Las Vegas, Nevada.
Livermore Herald, Livermore, California.
Los Angeles Times, Los Angeles, California.
Mariposa Gazette, Mariposa, California.
Mining Press, Reno, Nevada.

Mohave Miner, Kingman, Arizona.
Morning Union, Grass Valley, California.
Mountain Messenger, Downieville, California.
Needles Nugget, Needles, California.
Oroville Mercury Register, Oroville, California.
Placer Herald, Auburn, California.
Placerville Times, Placerville, California.
Plumas Independent, Quincy, California.
Randsburg Times, Randsburg, California.
Tehachapi News, Tehachapi, California.
Terra Bella News, Terra Bella, California.
Tuolumne Independent, Sonora, California.
Tuolumne Prospector, Tuolumne, California.
Union Democrat, Sonora, California.
Weekly Trinity Journal, Weaverville, California.
Yreka Journal, Yreka, California.

NEW BOOKS

Longwell, C. R., Knopf, A., and **Flint, R. F.,** A Textbook of Geology, Part I, Physical Geology, 543 pp., New York, John Wiley & Sons, Inc., 1939. (F. W. Bradley Memorial Book Fund).

Schuchert, C. and **Dunbar, C. O.,** A Textbook of Geology, Part II, Historical Geology, 544 pp., New York, John Wiley & Sons, Inc., 1941. (F. W. Bradley Memorial Book Fund).

Pringsheim, P., and **Vogel, M.,** Luminescence of Liquids and Solids, 200 pp., Interscience Publishers, Inc., New York, 1943.

The Engineering Index, 1943, 1234 pp., New York, Engineering Index, Inc.

LIST OF LIBRARIES AT WHICH DIVISION OF MINES PUBLICATIONS MAY BE CONSULTED*

By Beth Collins

OUTLINE OF REPORT

INTRODUCTION

Publications of the California State Division of Mines, in whole or in part, may be referred to in numerous offices and libraries throughout the United States; in the Territories of Alaska and Hawaii; and in various foreign countries.

The State of California division of the following publications-reference list contains first an alphabetical arrangement of the counties with the towns to which the publications have been supplied, and second an alphabetical arrangement of the towns with the libraries and offices.

The foreign division of the list was in effect until the outbreak of the war. The arrangement is alphabetical first by country, second by city, then by libraries and offices.

* Manuscript submitted for publication April 17, 1944.

CALIFORNIA

Index List of Counties

- Alameda
  - Alameda
  - Berkeley
  - Mills College
  - Oakland
- Amador
  - Jackson
- Butte
  - Chico
  - Oroville
- Colusa
  - Colusa
- Contra Costa
  - Martinez
  - Richmond
- Del Norte
  - Crescent City
- El Dorado
  - Placerville
- Fresno
  - Coalinga
  - Fresno
- Glenn
  - Willows
- Humboldt
  - Arcata
  - Eureka
- Imperial
  - El Centro
- Inyo
  - Independence
- Kern
  - Bakersfield
  - Mojave
  - Randsburg
  - Taft
- Kings
  - Hanford
- Lake
  - Lakeport
- Lassen
  - Susanville
- Los Angeles
  - Alhambra
  - Claremont
  - Compton
  - Glendale
  - Hollywood (North)
  - Long Beach
  - Los Angeles
  - North Hollywood
  - Pasadena
- Los Angeles—Continued
  - Pasadena (South)
  - Pomona
  - Santa Monica
  - South Pasadena
  - Whittier
- Madera
  - Madera
- Mariposa
  - Mariposa
  - Yosemite National Park
- Merced
  - Los Banos
  - Merced
- Monterey
  - Carmel
  - Monterey
  - Salinas
- Napa
  - Veterans Home
- Nevada
  - Grass Valley
  - Nevada City
- Orange
  - Anaheim
  - Balboa
  - Fullerton
  - Orange
  - Santa Ana
- Placer
  - Auburn
  - Roseville
- Plumas
  - Quincy
- Riverside
  - Beaumont
  - Blythe
  - Hemet
  - Riverside
- Sacramento
  - Sacramento
- San Benito
  - Hollister
- San Bernardino
  - Chino
  - Fontana
  - Redlands
  - San Bernardino
- San Diego
  - Chula Vista
  - San Diego
- San Francisco
  - San Francisco
- San Joaquin
  - Lodi
  - Stockton
- San Mateo
  - San Mateo
- San Luis Obispo
  - Paso Robles
  - San Luis Obispo
- Santa Barbara
  - Santa Barbara
  - Santa Maria
- Santa Clara
  - Palo Alto
  - San Jose
  - Santa Clara
  - Stanford University
- Santa Cruz
  - Santa Cruz
- Shasta
  - Redding
- Siskiyou
  - Yreka
- Solano
  - Fairfield
  - Vallejo
- Sonoma
  - Petaluma
  - Santa Rosa
- Stanislaus
  - Modesto
- Sutter
  - Yuba City
- Tehama
  - Red Bluff
- Trinity
  - Weaverville
- Tulare
  - Visalia
- Tuolumne
  - Sonora
- Ventura
  - Santa Paula
  - Ventura
- Yolo
  - Woodland
- Yuba
  - Marysville

Index List of Towns

Alameda, Alameda County
  Alameda Free Library, J. I. Curtis Section.
  Alameda High School Library.
Alhambra, Los Angeles County
  Alhambra Public Library, 410 West Main Street.
  Los Angeles Mineralogical Society, 58 Hampden Terrace.
Anaheim, Orange County
  Anaheim Public Library, 241 South Los Angeles Street.
Arcata, Humboldt County
  Humboldt State College Library.
Auburn, Placer County
  Auburn Free Public Library, 175 Almond Street.
  Metals Reserve Company Ore Purchasing Depot.
  Placer County Free Library.
Bakersfield, Kern County
  Bakersfield Chamber of Commerce, 1703 Chester Avenue.
  California State Division of Oil & Gas, 1101 Golden State Highway.
  Kern County Chamber of Commerce.
  Kern County Free Library.
  Kern County Union High School and Junior College Library.
Balboa, Orange County
  Newport Beach Public Library, 106 Island Avenue.
Beaumont, Riverside County
  Beaumont District Library.
Berkeley, Alameda County
  Berkeley Public Library.
  University of California—
    Bancroft Library.
    Geology Department, Bacon Hall.
    Library, Documents Division.
    Mining Department Library, Hearst Memorial Mining Building.
    Division of Soils, 122 Hilgard Hall.
    U. S. Bureau of Mines, Hearst Memorial Mining Building.
Blythe, Riverside County
  Blythe Public Library.
Carmel, Monterey County
  Carmel Public Library, Box 800.
Chico, Butte County
  Chico Public Library.
  Chico State College Library.
Chino, San Bernardino County
  California Institution for Men Library.
Chula Vista, San Diego County
  Chula Vista Public Library.
Claremont, Los Angeles County
  Pomona College Library.
Coalinga, Fresno County
  California State Division of Oil & Gas, 466 North Fifth Street.
  Coalinga District Library.
Colusa, Colusa County
  Colusa County Free Library.
Compton, Los Angeles County
  Compton Junior College, Geology Department, 601 South Acacia Street.
Crescent City, Del Norte County
  Del Norte County Library.
  Del Norte Miners Association, 896 Second Street.
El Centro, Imperial County
  El Centro Public Library.
  Imperial County Free Library.
Eureka, Humboldt County
  Eureka Chamber of Commerce.
  Eureka Free Library.
Fairfield, Solano County
  Solano County Free Library.

Fontana, San Bernardino County
San Bernardino County Chamber of Commerce.
Fresno, Fresno County
Fresno County Chamber of Commerce.
Fresno County Free Library, 1330 Broadway.
Fresno State College Library.
Fullerton, Orange County
Fullerton Junior College Library.
Fullerton Public Library, 410 North Spadra.
Glendale, Los Angeles County
Glendale Junior College Library, 1500 North Verdugo.
Glendale Public Library, 319 East Harvard Street.
Glendale Unified School District, 411 East Wilson Avenue.
Grass Valley, Nevada County
Grass Valley Chamber of Commerce, 219 West Main Street.
Grass Valley Public Library.
Hanford, Kings County
Kings County Free Library.
Hemet, Riverside County
Hemet Public Library.
Hollister, San Benito County
San Benito County Free Library.
Hollywood (North), Los Angeles County
Los Angeles Public Library, Sidney Lanier Branch, 511 Tujunga Avenue.
Independence, Inyo County
Inyo County Assessor and Tax Collector.
Inyo County Free Library.
Jackson, Amador County
Amador County Free Library.
Lakeport, Lake County
Lakeport Carnegie Library.
Lodi, San Joaquin County
Lodi Public Library, 305 West Pine Street.
Long Beach, Los Angeles County
Long Beach Public Library, Document Department.
Long Beach Public Schools for Adult Education, 275 Tivoli Drive.
Los Angeles, Los Angeles County
California Oil & Gas Association, 510 West Sixth Street—1217.
California State Corporation Department, 403 State Building, 217 West First Street.
California State Division of Mines, State Building, 217 West First Street.
California State Division of Real Estate, 325 West Eighth Street—601.
Los Angeles Chamber of Commerce, Research Department.
Los Angeles Chamber of Commerce, Mining Department.
Los Angeles City College, 855 North Vermont Avenue.
Los Angeles County Library, 322 South Broadway.
Los Angeles Junior College, Geology Department, 855 North Vermont Avenue.
Los Angeles Public Library—
Arroyo Seco Branch, 6145 North Figueroa Street.
Cahuenga Branch, 4591 Santa Monica Blvd.
Municipal Reference Branch, Power & Light Division, 200 North Spring Street.
Serials Division, 530 South Hope Street.
Vermont Square Branch, 1201 West Forty-eighth Street.
Vernon Branch, 4504 Central Avenue.
Occidental College Library.
Sixth District Agricultural Association Information Bureau, Exposition Park.
Southern California Academy of Science, Exposition Park.
Union Oil Company, Geological Library, Union Oil Building.
University of California at Los Angeles Library, 405 Hilgard Avenue.
University of California at Los Angeles, Geology Department, 405 Hilgard Avenue.
University of Southern California Library, University Park.
U. S. Bureau of Mines, Petroleum Economics Division, 1545 Post Office Building.
U. S. Geological Survey, 533 Post Office & Court House.
Westmont College, 231 South Westmoreland Avenue.

Los Banos, Merced County
  Merced County Chamber of Commerce.
Madera, Madera County
  Madera County Chamber of Commerce.
  Madera County Free Library.
Mariposa, Mariposa County
  Mariposa Chamber of Commerce.
Martinez, Contra Costa County
  Contra Costa County Library, 119 Hall of Records.
Marysville, Yuba County
  Marysville City Library, 301 Fourth Street.
Merced, Merced County
  Merced County Free Library.
Mills College, Alameda County
  Mills College Library.
Modesto, Stanislaus County
  McHenry Public Library.
  Stanislaus County Free Library.
Mojave, Kern County
  Kern County Free Library, Mojave Branch.
Monterey, Monterey County
  Monterey Public Library.
Nevada City, Nevada County
  Nevada City Free Library.
North Hollywood, Los Angeles County
  Los Angeles Public Library, Sidney Lanier Branch, 5211 Tujunga Avenue.
Oakland, Alameda County
  Oakland Chamber of Commerce, Industrial Department, Financial Center Building.
  Oakland Free Library, Fourteenth and Grove Streets.
Orange, Orange County
  Orange Public Library.
Oroville, Butte County
  Butte County Free Library.
  Oroville and Allied Communities Chamber of Commerce, 2076 Bird Street.
  Oroville Public Library.
Palo Alto, Santa Clara County
  Palo Alto Public Library, Reference Department.
Pasadena, Los Angeles County
  California Institute of Technology Library, 1201 California Street.
  Pasadena Junior College, Geology Department.
  Pasadena Public Library, 285 East Walnut Street.
  South Pasadena Public Library, 1101 El Centro.
Paso Robles, San Luis Obispo County
  Paso Robles Public Library.
Petaluma, Sonoma County
  Petaluma Public Library.
Placerville, El Dorado County
  El Dorado County Chamber of Commerce.
  Placerville City and County Public Library, City Hall.
Pomona, Los Angeles County
  Pomona Public Library, Documents Division.
Quincy, Plumas County
  Plumas County Free Library.
Randsburg, Kern County
  Kern County Free Library, Randsburg Branch.
Red Bluff, Tehama County
  Tehama County Free Library.
Redding, Shasta County
  California State Division of Mines, Chamber of Commerce Building.
  Redding Public Library.
Redlands, San Bernardino County
  University of Redlands Library.
Richmond, Contra Costa County
  Richmond Public Library.

Riverside, Riverside County
- Riverside Chamber of Commerce.
- Riverside County Chamber of Commerce, County Court House.
- Riverside Public Library.

Roseville, Placer County
- Roseville Public Library.

Sacramento, Sacramento County
- California State Chamber of Commerce, Chamber of Commerce Building.
- California State Debris Commission, 1209 Eighth Street.
- California State Division of Corporations, Department of Investment.
- California State Board of Equalization, Valuation Division, 1020 N Street.
- California State Division of Highways, 1120 N Street.
- California State Division of Water Resources, 401 Public Works Building.
- California Division of State Lands, 1020 N Street.
- California State DIVISION OF MINES, 401 State Office Building.
- California State Personnel Board, 1015 L Street.
- California State Reclamation Board, 1000 O Street.
- Sacramento Junior College Library.
- Sacramento City Library.
- U. S. District Land Office, 352 Post Office Building.
- U. S. Bureau of Reclamation, Old Post Office Building.

Salinas, Monterey County
- Salinas Public Library.

San Bernardino, San Bernardino County
- San Bernardino Chamber of Commerce, 533 E Street.
- San Bernardino County Free Library.
- San Bernardino Public Library.

San Diego, San Diego County
- Bureau of Mines of San Diego County, 3327 North Mountain View.
- San Diego County Free Library, 3532 Meade.
- San Diego Public Library, E Street near Eighth.
- San Diego Society of Natural History, Natural History Museum, Balboa Park.
- San Diego State College, Geology Department.

San Francisco, San Francisco County
- California Academy of Sciences Library, Golden Gate Park.
- California Historical Society, 456 McAllister Street.
- California Metal & Mineral Producers Association, 300 Montgomery Street.
- California School of Mechanical Arts Library, 2250 Seventeenth Street.
- California State Chamber of Commerce, 350 Bush Street.
- California State Industrial Accident Commission, State Building, Civic Center.
- California State Division of Corporations, State Building, Civic Center.
- California State DIVISION OF MINES, main office, Ferry Building.
- California State Railroad Commission, State Building, Civic Center.
- Mechanics Institute Library, 57 Post Street.
- Reconstruction Finance Corporation, Mining Section, 200 Bush Street.
- San Francisco Junior Museum, 600 Ocean Avenue.
- San Francisco Public Library, Civic Center.
- San Francisco State College Library, Buchanan and Waller Streets.
- Sierra Club, Mills Tower.
- U. S. Department of Agriculture Library, Forest Service, Appraisers Building.
- U. S. Department of Commerce Regional Office, 307 U. S. Custom House.
- U. S. Bureau of Mines, Mineral Products and Economics Division, 206 Post Office Building.
- U. S. Bureau of Mines, Clunie Building.
- U. S. Veterans Administration Library, Fort Miley.
- University of San Francisco, 2130 Fulton Street.

San Jose, Santa Clara County
- Santa Clara County Library, Hall of Justice.
- San Jose Chamber of Commerce.
- San Jose Public Library.
- San Jose Teachers College Library.

San Luis Obispo, San Luis Obispo County
- San Luis Obispo Public Library, 690 Monterey Street.

San Mateo, San Mateo County
- San Mateo Public Library, 129 Second Avenue.

Santa Ana, Orange County
Orange County Free Library, Court House Annex.
Santa Ana Free Public Library.
Santa Ana Junior College Library, 917 North Main Street.
Santa Barbara, Santa Barbara County
Santa Barbara Free Public Library.
Santa Barbara Museum of Natural History.
Santa Barbara State College Library.
Santa Clara, Santa Clara County
Santa Clara University, Varsi Library.
Santa Clara University, College of Engineering.
Santa Cruz, Santa Cruz County
Carnegie Public Library.
Santa Cruz Public Library, Church Street.
Santa Maria, Santa Barbara County
California State Division of Oil and Gas, Drexler Building.
Santa Monica, Los Angeles County
Santa Monica Junior College Library.
Santa Monica Public Library.
Santa Paula, Ventura County
California State Division of Oil and Gas, Santa Paula Loan & Investment Building.
Dean Hobbs Blanchard Memorial Library.
Santa Rosa, Sonoma County
Santa Rosa Free Library.
Santa Rosa Junior College Library.
Sonora, Tuolumne County
Sonora Public Library.
Tuolumne County Chamber of Commerce.
Tuolumne County Free Library.
South Pasadena, Los Angeles County
South Pasadena Public Library, 1101 El Centro Street.
Stanford University, Santa Clara County
Branner Memorial Library, Geology Department.
Economic Geology Department.
Library.
Mining Department.
Stockton, San Joaquin County
College of the Pacific Library.
Stockton Chamber of Commerce, 234 North El Dorado Street.
Stockton Public Library.
Susanville, Lassen County
Lassen County Free Library.
Taft, Kern County
California State Division of Oil and Gas.
Taft Public Library, North Street.
Vallejo, Solano County
Vallejo Public Library.
Ventura, Ventura County
Ventura College Library, 2155 East Main Street.
Ventura County Free Library.
Veterans Home of California, Napa County
Veterans Home Library.
Visalia, Tulare County
Tulare County Free Library.
Visalia Public Library, Locust and Oak Streets.
Weaverville, Trinity County
Trinity County Free Library.
Whittier, Los Angeles County
Whittier Public Library, Greenleaf and Bailey Streets.
Willows, Glenn County
Glenn County Free Library, American Legion Building.
Woodland, Yolo County
Yolo County Free Library.
Yosemite National Park, Mariposa County
Park Naturalist.

Yreka, Siskiyou County
Siskiyou County Free Library.
U. S. Forest Supervisor, Klamath National Forest.
Yreka Chamber of Commerce.
Yuba City, Sutter County
Sutter County Free Library, Mission Hall.
Yuba City High School Library.

UNITED STATES, OTHER THAN CALIFORNIA

ALABAMA
Birmingham
Birmingham Public Library, Technology Department.
University
Alabama Geological Survey, Alabama State University.
Alabama State University, Geology Department.

ARIZONA
Phoenix
Arizona State Department of Mineral Resources, 413 Home Builders Building.
Tucson
Arizona Bureau of Mines, Arizona State University.
U. S. Bureau of Mines, Experiment Station, Box 4097.

ARKANSAS
Little Rock
Arkansas Geological Survey, 447 Arkansas State Capitol.

COLORADO
Boulder
Colorado State University Libraries.
Denver
Colorado Bureau of Mines, Colorado State Capitol.
Colorado Metal Mining Fund, 402 State Office Building, Colorado State Capitol.
Denver Public Library, Technology Department.
U. S. Bureau of Mines, 519 Custom House.
Golden
Colorado State School of Mines Library.

CONNECTICUT
Bridgeport
Bridgeport Public Library, Burroughs Building.
Hartford
Connecticut Geological and Natural History Survey, Connecticut State Library.
Middletown
Wesleyan University, Geology Department.
New Haven
Yale University Geology Department, Kirtland Hall.
Yale University Library, Serial Department.

FLORIDA
Gainsville
Florida State University Library.
Tallahassee
Florida State Geological Survey, P. O. Drawer 631.

GEORGIA
Atlanta
Georgia Division of Mines, Mining and Geology, Georgia State Capitol.

IDAHO
Boise
Idaho State Mine Inspector.
Moscow
Idaho Bureau of Mines and Geology, Idaho State University.

ILLINOIS

Chicago
- Chicago Public Library, Accessions Department, Washington Street and Michigan Avenue.
- Chicago Natural History Museum.
- John Crerar Library, Michigan Avenue and Randolph Street.
- University of Chicago Libraries, Periodical Division, Harper M 22.

Evanston
- Northwestern University Library, Document Department.

Urbana
- Illinois State University Library.
- Illinois Geological Survey, Illinois State University.

INDIANA

Indianapolis
- Indiana State Library.

IOWA

Ames
- Iowa State College Library.

Iowa City
- Iowa Geological Survey, Geology Annex, Iowa State University.

KANSAS

Lawrence
- Kansas State University Library.
- Kansas Geological Survey, Kansas State University.

KENTUCKY

Lexington
- Kentucky Geological Survey, Mining Engineering Building, Kentucky State University.
- Kentucky State University Library.

LOUISIANA

Baton Rouge
- Louisiana Geological Survey, Louisiana State University.
- Louisiana State University, Geology Library.

Lafayette
- Southwest Louisiana Institute, Stephens Memorial Library.

New Orleans
- Louisiana Minerals Division, Louisiana State Department of Conservation, 111 Civil District Court Building.

MARYLAND

Baltimore
- Enoch Pratt Free Library, Cathedral, Franklin and Mulberry Streets.
- Maryland State Department of Geology, Mines and Water Resources, Johns Hopkins University.
- U. S. Bureau of Mines, Division of Geophysical Exploration, 409 Custom House.

MASSACHUSETTS

Boston
- Baker Library, Soldiers Field, Harvard University.
- Massachusetts State Library, Massachusetts State House.

Cambridge
- Harvard University, Museum of Comparative Zoology.
- Massachusetts Institute of Technology Library.

MICHIGAN

Ann Arbor
- Michigan State University General Library.

Detroit
- Detroit Public Library.

Houghton
- Michigan College of Mining and Technology Library.

Lansing
- Michigan Geological Survey, Department of Conservation, State Office Building.

East Lansing
- Michigan State College Library.

MINNESOTA
Minneapolis
Minneapolis Public Library.
Minnesota Geological Survey, Minnesota State University.
Minnesota State University Library.
St. Paul
James Jerome Hill Reference Library.

MISSOURI
Columbia
Missouri State University General Library.
Kansas City
Kansas City Public Library, Document Department.
Rolla
Missouri State School of Mines and Metallurgy Library.
St. Louis
St. Louis Public Library, Olive, 13th and 14th Streets.
Washington University Library, Skinner and Lindell Blvd.
Washington University, Geology Department.

MONTANA
Butte
Montana School of Mines.
Missoula
Montana State University Library, Documents and Serials Department.

NEBRASKA
Lincoln
Nebraska Geological Survey, Nebraska State University.
Omaha
Union Pacific Railway Company, Agricultural Development.

NEVADA
Carson City
Nevada State Inspector of Mines.
Reno
Mackay School of Mines, Nevada State University.
U. S. Bureau of Mines, Metals Experiment Station.

NEW HAMPSHIRE
Hanover
Dartmouth College Library.

NEW JERSEY
Newark
University of Newark, Geology Department.
New Brunswick
Rutgers University Library.
Princeton
Princeton University Library.
Trenton
New Jersey Geological Survey, Department of Conservation and Development, New Jersey State House Annex.

NEW MEXICO
Albuquerque
New Mexico State University Library.
Socorro
New Mexico State School of Mines.

NEW YORK
Albany
New York State Library.
Hamilton
Colgate University Library.
Ithaca
Cornell University Library.
New York City
American Bureau of Metal Statistics, 33 Rector Street.
American Geographical Society, Boardway at 156th Street.
American Institute of Mining Engineers, 29 West 39th Street.
American Petroleum Institute, 50 West 50th Street—2040.
Columbia University Libraries, Acquisition Department, South Hall.

New York—Continued

New York City—continued
- Engineering Societies Library, 29 West 39th Street.
- Marvin Scudder Financial Library, 231 South Hall, Columbia University.
- Mines Register, 133 West 21st Street.
- Mining and Metallurgical Society of America, School of Mines, Columbia University.
- New York Academy of Sciences, American Museum of Natural History, 77th Street and Central Park West.
- New York Public Library, 476 5th Avenue.
- Oil, Paint and Drug Reporter, 59 John Street.

Syracuse
- Syracuse University Library.

North Carolina

Chapel Hill
- North Carolina State University Library, Document Division.

Raleigh
- North Carolina State Department of Conservation & Development.
- North Carolina College of Agriculture & Engineering, North Carolina State University.

North Dakota

Grand Forks
- North Dakota Geological Survey, North Dakota State University.

Ohio

Cincinnati
- University of Cincinnati Library, Acquisition Department.

Cleveland
- Cleveland Public Library, 325 Superior Avenue, N. E.

Columbus
- Ohio Geological Survey, Orton Hall, Ohio State University.

Oberlin
- Oberlin College Library.

Toledo
- Toledo Public Library.

Oklahoma

Bartlesville
- U. S. Bureau of Mines, Petroleum Experiment Station.

Norman
- Oklahoma Geological Survey, Oklahoma State University.
- Oklahoma State University, Geological Library.

Stillwater
- Oklahoma A. & M. College Library.

Tulsa
- American Association of Petroleum Geologists, Box 979.
- University of Tulsa Library.

Oregon

Corvallis
- Oregon State College Library, Serials Division.

Eugene
- Oregon State University Library.

Portland
- Library Association of Portland, 10th and Yamhill Streets.
- Oregon State Department of Geology and Mineral Industries, Woodlark Building.
- U. S. Bonneville Power Administration, Technical Library, Box 3537.
- U. S. Engineer's Office, First Portland District, 628 Pittock Block.

Salem
- Oregon State Library.

Pennsylvania

Bethlehem
- Lehigh University Library.

8—36585

PENNSYLVANIA—Continued	Philadelphia Academy of Natural Sciences of Philadelphia Library, 19th and Parkway. Franklin Institute Library. Free Library of Philadelphia, Public Documents Department, Logan Square. Temple University, Political Science Department. University of Pennsylvania Library, 13th Street and Woodland Avenue. U. S. Securities & Exchange Commission, 18th and Locust Streets. Pittsburgh Carnegie Library, 4400 Forbes Street. U. S. Bureau of Mines Library, 4800 Forbes Street.
RHODE ISLAND	Providence Brown University Library.
SOUTH CAROLINA	Columbia South Carolina State University, Geology Department.
SOUTH DAKOTA	Rapid City South Dakota State School of Mines Library. Vermilion South Dakota State Geological Survey.
TENNESSEE	Nashville Tennessee Director of Geology, Tennessee State Office Building. Vanderbilt University, Geology Department. Norris U. S. Bureau of Mines.
TEXAS	Austin Texas Bureau of Economic Geology, Texas State University. Texas State University Library, Documents Acquisition Department. College Station Texas A. & M. College, Geology Department Library. El Paso El Paso Public Library, Carnegie Square. Texas College of Mines & Metallurgy, Texas State University. Houston Houston Public Library.
UTAH	Logan Utah State Agricultural College Library. Salt Lake City U. S. Bureau of Mines, 340 Federal Building. U. S. Bureau of Mines, Intermountain Experiment Station, 1600 East First South Street.
VIRGINIA	Charlottesville Virginia Geological Survey, Box 1428, Virginia State University.
WASHINGTON	Pullman Washington State College Library. Washington State Department of Conservation & Development, Geology Division. Seattle Seattle Public Library, Reference Department. Washington College of Mines, Washington State University. Washington State University Library, Gifts and Exchanges. Spokane Northwest Mining Association, 510 West First Avenue. Spokane Public Library, 18 Cedar Street. Tacoma Tacoma Public Library.

WEST VIRGINIA	Morgantown West Virginia State Geological Survey.
WISCONSIN	Madison Wisconsin State University, Geology Department Library. Wisconsin Geological Survey, Science Hall, Wisconsin State University. Milwaukee Milwaukee Public Library, 8th and Wisconsin Streets.
WYOMING	Laramie Wyoming Geological Survey, Wyoming State University.
WASHINGTON, D. C.	Federal Power Commission, 1800 Pennsylvania Avenue, N. W. National Sand & Gravel Association, Munsey Building. Smithsonian Institution. U. S. Director of the Census, Department of Commerce. U. S. Coast & Geodetic Survey, Division of Geodesy. U. S. Department of Commerce Library. U. S. Bureau of Foreign & Domestic Commerce. U. S. Congressional Library. U. S. Geological Survey, Metallurgical Department. U. S. Bureau of Mines Library. U. S. Bureau of Mines, Metals Economics Division. U. S. Bureau of Mines, Economics and Statistics Service. U. S. Bureau of Mines, Mineral Statistics Division. U. S. Public Roads Administration, Willow Building. U. S. Securities & Exchange Commission.

TERRITORIES

ALASKA	College Alaska School of Mines, University of Alaska.
TERRITORY OF HAWAII	Honolulu U. S. Geological Survey, Ground Water Division, 333 Federal Building.

FOREIGN

AFRICA, FRENCH WEST	Dakar Services des Mines, Government General, Office of the Director.
AFRICA, SOUTH	Johannesburg Transvaal Chamber of Mines, 5 Hollard Street.
AUSTRALIA	Adelaide Adelaide University, Barr Smith Library. Public Library, Museum and Art Gallery. South Australia Department of Mines. Brisbane Queensland Geological Survey. Calgoorlie Chamber of Mines of West Australia. Melbourne Australian Institute of Mining & Metallurgy, 374 Little Collins Street. Chemical Engineering and Mining Review, 349 Collins Street. Mining Department. Perth Western Australia Geoolgical Survey. Sydney Geological Survey of New South Wales. Public Library of New South Wales.

Canada

Gardenvale, Quebec
  Canadian Mining Journal, National Business Publications, Ltd.
Halifax, Nova Scotia
  Nova Scotia Commissioner of Mines.
Montreal, Quebec
  Canadian Institute of Mining & Metallurgy, Drummond Bldg.
Ottawa, Ontario
  Department of Mines & Resources, Bureau of Mines Library.
  Geological Survey of Canada.
Quebec, Quebec
  Department of Geologie, Canadian Naturalist, Universite Laval.
Toronto, Ontario
  Ontario Department of Mines, Parliament Bldg.
Vancouver, British Columbia
  Canadian Geological Survey, B. C. Branch, 510 Winch Bldg.
  University of British Columbia Library.
Victoria, British Columbia
  B. C. Department of Mines.
Winnipeg, Manitoba
  Manitoba Department of Mines & Natural Resources, Mining Branch.

England

London
  The Gemologist, 26-34 Old Street, E. C. 1.
  Geological Society of London, Burlington House, W. 1.
  Geological Survey & Museum, Exhibition Road, South Kensington, S. W. 7.
  Imperial College of Science & Technology, Department of Geology, South Kensington, S.W. 7.
  Institution of Mining & Metallurgy, Royal School of Mines, Salisbury House, Finsbury Circus, E. C. 2.
  The Mining Journal, Mansion House, 15 George Street, E. C.
  Patent Office Library, 25 Southhampton Bldg., W. C. 2.
  The Science Museum, South Kensington, S.W. 7.

Mexico

Mexico City
  Instituto Geologico de Mexico, 6 Calle del Cipres No. 176.
  Secretaria de Industria y Commercio, Seccion de Biblioteca y Publicaciones.

New Zealand

Wellington
  New Zealand Department of Mines.
  New Zealand Geological Survey.

Russia

Leningrad
  Academy of Sciences U. S. S. R. Birzhevaya 1.
  Central Geological Library, Sredny Pr., W. O.
Moscow
  Institute of Mineral Resources.

South America

Buenos Aires, Argentina
  Argentina Direccion General de Minas y Geologia, Ministerio de Agricultura, Peru 566.
Caracas, Venezuela
  Ministerio de Educacion Nacional, Instituto de Geologia, Avenida San Martin.
Lima, Peru
  Cuerpo de Ingenieros de Minas, Apartado Correo 889.
  Ministerio de Fomento, Direccion de Minas.
Montevideo, Uruguay
  Instituto Geologico del Uruguay, No. L1239L10, Herrera y Obes.
Rio de Janeiro, Brazil
  Museu Nacional, Universidade do Brasil.
  Ministerio da Agricultura, Department Nacional de Produccao Mineral Bibliotheca, Avenida Pasteur, Praia Vermelha.

SPAIN	Barcelona Secretario de la Real Academia de Ciencias y Artes.
SWEDEN	Stockholm Sveriger Geologiska Undersokning. Uppsala University of Uppsala, Geological Institution.

SERVICES OF THE DIVISION OF MINES

The Division of Mines (formerly State Mining Bureau) is maintained for the purpose of assisting in all possible ways in the development of California's mineral resources.

As one means of offering tangible service to the mining public, the State Mineralogist for many years has issued an annual or a biennial report reviewing in detail the mines and mineral deposits of the various counties.

As a progressive step in advancing the interests of the mineral industry, and as permitting earlier distribution to the public, publication of the Annual Report of the State Mineralogist in the form of monthly chapters was begun in January 1922, and continued until March 1923. Owing to a lack of funds for printing this was changed to a quarterly publication, beginning in September 1923. For the same reason, beginning with the January 1924 issue, it became necessary to charge a subscription price. This covers approximately the cost of printing.

Pages are numbered consecutively throughout the year and an index to the complete report is included annually in the closing number.

Beginning with the 1930 issues, the activities and progress of the Geologic Branch are recorded also in these quarterly chapters. The important part that geology plays in the economic development of our mineral resources is further recognized in the change of title from *Mining in California* to CALIFORNIA JOURNAL OF MINES AND GEOLOGY, beginning with the January 1933 chapter.

While current activities of all descriptions are covered in these chapters, the practice of issuing from time to time technical reports on special subjects will be continued as well. A list of such reports now available is appended hereto, and the names of new bulletins will be added in the future as they are completed.

The chapters are subject to revision, correction and improvement. Constructive suggestions from the mining public will be gladly received, and are invited.

The one aim of the Division of Mines is to increase its usefulness and to stimulate the intelligent development of the wonderful, latent resources of the State of California.

TYPES OF REPORTS

In general the reports presented in these chapters are grouped into three classes:

1. Mines and mineral resources of a given county or area (describing kind, character, distribution and extent of development).

2. Specific economic and industrial mineral products (listing and describing the resources over the entire State of a given mineral substance, e.g., feldspar).

3. Geological reports on specific areas (recording results and conclusions with maps, derived from field studies; and tied in with economic possibilities and developments).

Reports of District Mining Engineers

In 1919-1920 the Mining Bureau was organized into four main geographical divisions, with the field work delegated to a mining engineer in each district, working out from field offices that were established in Redding, Auburn, San Francisco and Los Angeles, respectively. This move brought the office into closer personal contact with operators, and it has many advantages over former methods of conducting field work, including lower traveling-expense bills for the Bureau's engineers. In 1923 the Redding and Auburn field offices were consolidated and moved to Sacramento.

The Redding office was reestablished in 1928, and the boundaries of each district adjusted. The counties now included in each of the four divisions and the locations of the branch offices are shown on the frontispiece outline map of the State.

Reports of mining activities and development in each district, prepared by the District Engineer, will continue to appear under the proper field division heading.

Special Articles

Detailed technical reports on special subjects, the result of research work or extended field investigations, will continue to be issued as separate bulletins by the Division, as has been the custom in the past.

Shorter and less elaborate technical papers and articles by members of the staff and others are published in each number of CALIFORNIA JOURNAL OF MINES AND GEOLOGY.

These special articles cover a wide range of subjects both of historical and current interest; descriptions of new processes, or metallurgical and industrial plants, new mineral occurrences, and interesting geological formations, as well as articles intended to supply practical and timely information on the problems of the prospector and miner, such as the text of new laws and official regulations and notices affecting the mineral industry.

MAIL AND FILES

The Division of Mines maintains, in addition to its correspondence files and the library, a mine file which includes original reports on the various mines and mineral properties of all kinds in California.

During each quarterly period there are several thousand letters received and answered at the San Francisco office alone, covering almost every phase of prospecting, mining and developing mineral deposits, reduction problems, marketing of refined products and mining law. In addition to this, hundreds of oral questions are answered daily, both at the main office and the district offices, for the many inquirers who come in for personal interviews and to consult the files and library.

COMMERCIAL MINERAL NOTES

The producer and consumer of mineral products are mutually dependent upon each other for their prosperity, and one of the most direct aids rendered by this Division to the mining industry in the past has been that of bringing producers and consumers into direct touch with each other.

This work has been carried on largely by correspondence, supplemented by personal consultation. Lists of buyers of all the commercial minerals produced in California have been made available to producers upon request, and likewise the owners of undeveloped deposits of various minerals, and producers of them, have been made known to those looking for raw mineral products.

When the publication of *Mining in California* was on a monthly basis, current inquiries from buyers and sellers were summarized and lists of mineral products or deposits 'wanted' or 'for sale' included in each issue.

It is important that inquiries of this nature reach the mining public as soon as possible and in order to avoid the delay incident to the present quarterly publication of CALIFORNIA JOURNAL OF MINES AND GEOLOGY, these lists are now issued monthly in the form of a mimeographed sheet under the title of 'Commercial Mineral Notes,' and sent to those on the mailing list of CALIFORNIA JOURNAL OF MINES AND GEOLOGY.

EMPLOYMENT SERVICE

Following the establishment of the Mining Division branch offices in 1919, a free technical employment service was offered as a mutual aid to mine operators and technical men for the general benefit of the mineral industry.

Briefly summarized, men desiring positions are registered, the cards containing an outline of the applicant's qualifications, position wanted, salary desired, etc., and as notices of 'positions open' are received, the names and addresses of all applicants deemed qualified are sent to the prospective employer for direct negotiations.

Telephone and telegraphic communications are also given immediate attention.

Technical men, or those qualified for supervisory positions, and vacancies of like nature only, are registered, as no attempt will be made to supply mine and mill labor.

Registration cards for the use of both prospective employers and employees may be obtained upon request, and a cordial invitation is extended to the industry to make free use of the facilities afforded. Parties interested should communicate direct with our San Francisco office.

DETERMINATION OF MINERAL SAMPLES

Samples (limited to two at one time) of any mineral found in the State may be sent to the Division of Mines for identification, and the same will be classified free of charge. No samples will be determined if received from points outside the State. It must be understood that no assays, or quantitative determinations will be made. Samples should be in lump form if possible, and marked plainly with name of sender on outside of package, etc. No samples will be received unless delivery charges are prepaid. A letter should accompany sample, giving locality where mineral was found and the nature of the information desired.

PUBLICATIONS OF THE DIVISION OF MINES

During the past sixty-four years, in carrying out the provisions of the organic act creating the former California State Mining Bureau, there have been published many reports, bulletins and maps which go to make up a library of detailed information on the mineral industry of the State, a large part of which could not be duplicated from any other source.

One feature that has added to the popularity of the publications is that many of them have been distributed without cost to the public, and even the more elaborate ones have been sold at a price which barely covers the cost of printing.

Owing to the fact that funds for advancing the work of this department have usually been limited, the reports and bulletins mentioned are printed in limited editions many of which are now entirely exhausted.

Copies of such publications are available for reference, however, in the offices of the Division of Mines, in the Ferry Building, San Francisco; State Building, Los Angeles; State Office Building No. 1, Sacramento; Redding; and Division of Oil and Gas at Santa Barbara, Santa Paula, Taft, Bakersfield, Coalinga. They may also be found in many public, private and technical libraries in California and other states and foreign countries.

A catalog of all publications from 1880 to 1917, giving a synopsis of their contents, is issued as Bulletin No. 77.

Publications in stock may be obtained postpaid by addressing the San Francisco, Los Angeles or Sacramento offices and enclosing the requisite amount.

Remittances of stamps in an amount not to exceed 26 cents, currency or coin will be accepted at sender's risk. Payment is preferred in the form of money orders.

Money orders should be made payable to the Division of Mines.

Write for latest revised price list.

NOTE.—The Division of Mines frequently receives requests for some of the early Reports and Bulletins now out of print, and it will be appreciated if parties having such publications and wishing to dispose of them will advise this office.

REPORTS

Asterisks (**) indicate the publication is out of print.

	Price (including postage and sales tax)
**First Annual Report of the State Mineralogist, 1880, 43 pp. Henry G. Hanks	----
**Second Annual Report of the State Mineralogist, 1882, 514 pp., 4 illustrations, 1 map. Henry G. Hanks	----
**Third Annual Report of the State Mineralogist, 1883, 111 pp., 21 illustrations. Henry G. Hanks	----
**Fourth Annual Report of the State Mineralogist, 1884, 410 pp., 7 illustrations. Henry G. Hanks	----
**Fifth Annual Report of the State Mineralogist, 1885, 234 pp., 15 illustrations, 1 geological map. Henry G. Hanks	----
**Sixth Annual Report of the State Mineralogist, Part I, 1886, 145 pp., 3 illustrations, 1 map. Henry G. Hanks	----
Part II, 1887, 222 pp., 36 illustrations. William Irelan, Jr. Price $0.75, sales tax $0.02	$0.77
**Seventh Annual Report of the State Mineralogist, 1887, 315 pp. William Irelan, Jr.	----
**Eighth Annual Report of the State Mineralogist, 1888, 948 pp., 122 illustrations. William Irelan, Jr.	----
**Ninth Annual Report of the State Mineralogist, 1889, 352 pp., 57 illustrations, 2 maps. William Irelan, Jr.	----
**Tenth Annual Report of the State Mineralogist, 1890, 983 pp., 179 illustrations, 10 maps. William Irelan, Jr.	----
Eleventh Report (First Biennial) of the State Mineralogist, for the two years ending September 15, 1892, 612 pp., 73 illustrations, 4 maps. William Irelan, Jr. Price $1.50, sales tax $0.04	1.54
**Twelfth Report (Second Biennial) of the State Mineralogist, for the two years ending September 15, 1894, 541 pp., 101 illustrations, 5 maps. J. J. Crawford	----
**Thirteenth Report (Third Biennial) of the State Mineralogist, for the two years ending September 15, 1896, 726 pp., 93 illustrations, 1 map. J. J. Crawford	----
Chapters of the State Mineralogist's Report, XIV Biennial Period, 1913, 1914, Fletcher Hamilton:	
**Mines and Mineral Resources, Amador, Calaveras and Tuolumne Counties, 172 pp., paper	----
Mines and Mineral Resources, Colusa, Glenn, Lake, Marin, Napa, Solano, Sonoma and Yolo Counties, 208 pp., paper Price $0.50, sales tax $0.01	.51
**Mines and Mineral Resources, Del Norte, Humboldt and Mendocino Counties, 59 pp., paper	----
**Mines and Mineral Resources, Fresno, Kern, Kings, Madera, Mariposa, Merced, San Joaquin and Stanislaus Counties, 220 pp., paper	----
**Mines and Mineral Resources of Imperial and San Diego Counties, 113 pp., paper	----
**Mines and Mineral Resources, Shasta, Siskiyou and Trinity Counties, 180 pp., paper	----
**Fourteenth Report of the State Mineralogist, for the Biennial Period 1913-1914, Fletcher Hamilton, 1915: A General Report on the Mines and Mineral Resources of Amador, Calaveras, Tuolumne, Colusa, Glenn, Lake, Marin, Napa, Solano, Sonoma, Yolo, Del Norte, Humboldt, Mendocino, Fresno, Kern, Kings, Madera, Mariposa, Merced, San Joaquin, Stanislaus, San Diego, Imperial, Shasta, Siskiyou and Trinity Counties, 974 pp., 275 illustrations, cloth	----
Chapters of the State Mineralogist's Report, XV Biennial Period, 1915-1916, Fletcher Hamilton:	
**Mines and Mineral Resources, Alpine, Inyo and Mono Counties, 176 pp., paper	----
Mines and Mineral Resources, Butte, Lassen, Modoc, Sutter and Tehama Counties, 91 pp., paper Price $0.50, sales tax $0.01	.51

REPORTS—Continued

Asterisks (**) indicate the publication is out of print. Price (including postage and sales tax)

**Mines and Mineral Resources, El Dorado, Placer, Sacramento and Yuba Counties, 198 pp., paper ---- ----

**Mines and Mineral Resources, Monterey, San Benito, San Luis Obispo, Santa Barbara and Ventura Counties, 183 pp., paper ----

Mines and Mineral Resources, Los Angeles, Orange and Riverside Counties, 136 pp., paper ---- Price $0.60, sales tax $0.02 $0.62

**Mines and Mineral Resources, San Bernardino and Tulare Counties, 186 pp., paper ---- ----

**Fifteenth Report of the State Mineralogist, for the Biennial Period 1915-1916, Fletcher Hamilton, 1917:

A General Report on the Mines and Mineral Resources of Alpine, Inyo, Mono, Butte, Lassen, Modoc, Sutter, Tehama, Placer, Sacramento, Yuba, Los Angeles, Orange, Riverside, San Benito, San Luis Obispo, Santa Barbara, Ventura, San Bernardino and Tulare Counties, 990 pp., 413 illustrations, cloth ---- ----

Chapters of the State Geologist's Report XVI, Biennial Period, 1917-1918, Fletcher Hamilton:

**Mines and Mineral Resources of Nevada County, 270 pp., paper ---- ----

Mines and Mineral Resources of Plumas County, 188 pp., paper ---- Price $0.50, sales tax $0.01 .51

Mines and Mineral Resources of Sierra County, 144 pp., paper ---- Price $0.75, sales tax $0.02 .77

Seventeenth Report of the State Mineralogist, 1920, 'Mining in California during 1920,' Fletcher Hamilton; 562 pp., 71 illustrations, cloth ---- Price $2.50, sales tax $0.06 2.56

Eighteenth Report of the State Mineralogist, 1922, 'Mining in California,' Fletcher Hamilton. Chapters published monthly beginning with January, 1922:

**January, **February, **March, **April, **May, **June, July, August, September, **October, November, **December, 1922 ---- Price $0.30, sales tax $0.01 .31

Chapters of Nineteenth Report of the State Mineralogist, 'Mining in California,' Fletcher Hamilton and Lloyd L. Root. January, February, March, September, 1923 ---- Price $0.30, sales tax $0.01 .31

Chapters of Twentieth Report of the State Mineralogist, 'Mining in California,' Lloyd L. Root. Published quarterly. January, April, October, 1924, per copy ---- Price $0.30, sales tax $0.01 .31

Chapters of Twenty-first Report of the State Mineralogist, 'Mining in California,' Lloyd L. Root. Published quarterly:

January, 1925, Mines and Mineral Resources of Sacramento, Monterey and Orange Counties ---- Price $0.30, sales tax $0.01 .31

**April, 1925, Mines and Mineral Resources of Calaveras, Merced, San Joaquin, Stanislaus and Ventura Counties ---- ----

**July, 1925, Mines and Mineral Resources of Del Norte, Humboldt and San Diego Counties ---- ----

**October, 1925, Mines and Mineral Resources of Siskiyou, San Luis Obispo and Santa Barbara Counties ---- ----

Chapters of Twenty-second Report of the State Mineralogist, 'Mining in California,' Lloyd L. Root. Published quarterly:

**January, 1926, Mines and Mineral Resources of Trinity and Santa Cruz Counties ---- ----

**April, 1926, Mines and Mineral Resources of Shasta, San Benito and Imperial Counties ---- ----

July, 1926, Mines and Mineral Resources of Marin and Sonoma Counties Price $0.30, sales tax $0.01 .31

**October, 1926, Mines and Mineral Resources of El Dorado and Inyo Counties, also report on Minaret District, Madera County ---- ----

REPORTS—Continued

Asterisks (**) indicate the publication is out of print. — Price (including postage and sales tax)

Publication	Price (including postage and sales tax)
Chapters of Twenty-third Report of the State Mineralogist, 'Mining in California,' Lloyd L. Root. Published quarterly:	
January, 1927, Mines and Mineral Resources of Contra Costa County; Santa Catalina Island — Price $0.30, sales tax $0.01	$0.31
April, 1927, Mines and Mineral Resources of Amador and Solano Counties — Price $0.30, sales tax $0.01	.31
**July, 1927, Mines and Mineral Resources of Placer and Los Angeles Counties	----
October, 1927, Mines and Mineral Resources of Mono County — Price $0.30, sales tax $0.01	.31
Chapters of Twenty-fourth Report of the State Mineralogist, 'Mining in California,' Lloyd L. Root. Published quarterly:	
January, 1928, Mines and Mineral Resources of Tuolumne County — Price $0.30, sales tax $0.01	.31
April, 1928, Mines and Mineral Resources of Mariposa County — Price $0.30, sales tax $0.01	.31
**July, 1928, Mines and Mineral Resources of Butte and Tehama Counties	----
**October, 1928, Mines and Mineral Resources of Plumas and Madera Counties	----
Chapters of Twenty-fifth Report of the State Mineralogist, 'Mining in California,' Walter W. Bradley. Published quarterly:	
January, 1929, Mines and Mineral Resources of Lassen, Modoc and Kern Counties; also on Special Placer Machines — Price $0.30, sales tax $0.01	.31
**April, 1929, Mines and Mineral Resources of Sierra, Napa, San Francisco and San Mateo Counties	----
July, 1929, Mines and Mineral Resources of Colusa, Fresno and Lake Counties — Price $0.30, sales tax $0.01	.31
October, 1929, Mines and Mineral Resources of Glenn, Alameda, Mendocino and Riverside Counties — Price $0.30, sales tax $0.01	.31
Chapters of Twenty-sixth Report of the State Mineralogist, 'Mining in California,' Walter W. Bradley. Published quarterly:	
January, 1930, Mines and Mineral Resources of Santa Clara County; also Barite in California — Price $0.40, sales tax $0.01	.41
**April, 1930, Mines and Mineral Resources of Nevada County; also Mineral Paint Materials in California	----
**July, 1930, Mines and Mineral Resources of Yuba and San Bernardino Counties; also Commercial Grinding Plants in California	----
October, 1930, Mines and Mineral Resources of Butte, Kings and Tulare Counties; also Geology of Southwestern Mono County (Preliminary) — Price $0.40, sales tax $0.01	.41
Chapters of Twenty-seventh Report of the State Mineralogist, 'Mining in California,' Walter W. Bradley. Published quarterly:	
January, 1931. Preliminary Report of Economic Geology of the Shasta Quadrangle. Beryllium and Beryl. The New Tariff and Nonmetallic Products. Crystalline Talc. Decorative Effects in Concrete — Price $0.40, sales tax $0.01	.41
April, 1931, Stratigraphy of the Kreyenhagen Shale. Diatoms and Silicoflagellates of the Kreyenhagen Shale. Foraminifera of the Kreyenhagen Shale. Geology of Santa Cruz Island — Price $0.40, sales tax $0.01	.41
**July, 1931. (Yuba, San Bernardino.) Feldspar, Silica, Andalusite and Cyanide Deposits of California. Note on a Deposit of Andalusite in Mono County; its occurrence and chemical importance. Bill creating Trinity and Klamath River Fish and Game District and its effect upon mining	----
October, 1931. (Alpine.) Geology of the San Jacinto Quadrangle south of San Gorgonio Pass, California. Notes on Mining Activities in Inyo and Mono Counties in July, 1931 — Price $0.40, sales tax $0.01	.41

REPORTS—Continued

Asterisks (**) indicate the publication is out of print. — Price (including postage and sales tax)

Chapters of Twenty-eighth Report of the State Mineralogist, 'Mining in California,' Walter W. Bradley. Published quarterly:

January, 1932, Economic Mineral Deposits of the San Jacinto Quadrangle. Geology and Physical Properties of Building Stone from Carmel Valley. Contributions to the Study of Sediments. Sediments of Monterey Bay. Sanbornite ---- Price $0.40, sales tax $0.01 — $0.41

**April, 1932. Elementary Placer Mining Methods and Gold Saving Devices. The Pan, Rocker and Sluice Box. Prospecting for Vein Deposits. Bibliography of Placer Mining ---- ----

**Abstract from April quarterly: Elementary Placer Mining Methods and Gold Saving Devices. Types of Deposits, Simple Equipment. Special Machines. Dry Washing. Black Sand Treatment. Marketing of Products. Placer Mining Areas. Laws. Prospecting for Quartz Veins. Bibliography (mimeographed)

**July-October, (Ventura.) Report accompanying Geologic Map of Northern Sierra Nevada. Fossil Plants in Auriferous Gravels of the Sierra Nevada. Glacial and Associated Stream Deposits of the Sierra Nevada. Jurassic and Cretaceous Divisions in the Knoxville-Shasta Succession of California. Geology of a Part of the Panamint Range. Economic Report of a Part of the Panamint Range. Acquiring Mining Claims Through Tax Title. The Biennial Report of State Mineralogist ---- ----

Chapters of Report XXIX, 1933 (quarterly): title 'California Journal of Mines and Geology,' containing the following:

January-April. Gold Deposits of the Redding and Weaverville Quadrangles. Geologic Formations of the Redding-Weaverville District, Northern California. Geology of Portions of Del Norte and Siskiyou Counties. Applications of Geology to Civil Engineering. The Lakes of California. Discovery of Piedmontite in the Sierra Nevada. Tracing 'Buried River' Channel Deposits by Geomagnetic Methods. Geologic Map of Redding-Weaverville District, showing gold mines and prospects. Geologic map showing various mines and prospects of part of Del Norte and Siskiyou Counties ---- Price $1.00, sales tax $0.03 — 1.03

July-October. Gold Resources of Kern County. Limestone Deposits of the San Francisco Region. Limestone Weathering and Plant Associations of the San Francisco Region. Booming, Death Valley National Monument, California. Placer Mining Districts, Senate Bill 480. Navigable Waters, Assembly Bill 1543 ---- Price $1.00, sales tax $0.03 — 1.03

Chapters of Report XXX, 1934 (quarterly); titled 'California Journal of Mines and Geology,' containing the following:

January. Resurrection of Early Surfaces in the Sierra Nevada. Geology and Mineral Resources of Northeastern Madera County. Geology and Mineral Deposits of Laurel and Convict Basins, Southwestern Mono County. Notes on Sampling as Applied to Gold Quartz Deposits ---- Price $0.60, sales tax $0.02 — .62

April-July. Elementary Placer Mining in California and Notes on the Milling of Gold Ores ---- Price $1.00, sales tax $0.03 — 1.03

October. Current Mining Developments in Northern California. Current Mining Activity in Southern California. Geology and Mineral Resources of the Julian District, San Diego County. Geology and Mineral Resources of Elizabeth Lake Quadrangle. Dry Placers of Northern Mojave Desert. Biennial Report of State Mineralogist. Assessment Work Within Withdrawn Areas ---- Price $0.60, sales tax $0.02 — .62

Chapters of Report XXXI, 1935 (quarterly): titled 'California Journal of Mines and Geology,' containing the following:

**January. Review of Gold Mining in East-Central California. 1934. Current Mining Activities in the San Francisco District with Special Reference to Gold. Geological Investigation of the Clays of Riverside and Orange Counties, Southern California. Information regarding Mining Loans by the Reconstruction Finance Corporation ---- ----

REPORTS—Continued

Asterisks (**) indicate the publication is out of print. Price (including postage and sales tax)

April. A Geologic Section Across the Southern Peninsular Range of California. New Technique Applicable to the Study of Placers. Grubstake Permits____Price $0.60, sales tax $0.02 $0.62

July. Mines and Mineral Resources of Siskiyou County (with map). Dams for Hydraulic Mining Debris. Leasing System as Applied to Metal Mining. Mine Financing in California. New Laws Make Radical Change in Mining Rights____Price $0.60, sales tax $0.02 .62

October. Mines and Mineral Resources of San Luis Obispo County. Mineral Resources of Portions of Monterey and Kings Counties. Mining Activity at Soledad Mountain and Middle Buttes—Mojave District, Kern County. Geology of a Portion of the Perris Block, Southern California. Mineral Resources of a Portion of the Perris Block, Riverside County____Price $0.60, sales tax $0.02 .62

Chapters of Report XXXII, 1936 (quarterly) : titled 'California Journal of Mines and Geology,' containing the following:

January. Gold Mines of Placer County, including Drag-line Dredges. Geologic Report on Borax Lake, California__Price $0.60, sales tax $0.02 .62

April. Geology, Mining and Processing of Diatomite at Lompoc, Santa Barbara County. Essentials in Developing and Financing a Prospect into a Mine. Gold-bearing Veins of Meadow Lake District, Nevada County. Semi-Precious Gem Stone Collection in Division Museum___ Price $0.60, sales tax $0.02 .62

July. Mines and Mineral Resources of Calaveras County. Mining in California by Power Shovel. Assessment Work on Mining Claims Within Withdrawn Areas. Joshua Tree National Monument. Cost of Producing Quicksilver at a California Mine in 1931-1932. The Age of Mineral Utilization____Price $0.60, sales tax $0.02 .62

October. Mineral Resources of Lassen and Modoc Counties. Mechanics of Lone Mountain Landslides, San Francisco. Biennial Report of the State Mineralogist, Properties and Industrial Applications of Opaline Silica____Price $0.60, sales tax $0.02 .62

Chapters of Report XXXIII, 1937 (quarterly) : titled 'California Journal of Mines and Geology,' containing the following:

January. Source Data of the Geologic Map of California, January, 1937. The Geology of Quicksilver Ore Deposits. Prospecting for Lode Gold__ Price $0.60, sales tax $0.02 .62

April. Mineral Resources of Plumas County (with Geologic Map). List of preferred mineral names. New Placer Mining Debris Law____ Price $0.60, sales tax $0.02 .62

July. Mineral Resources of Los Angeles County (with map showing principal Mines and Oil Fields). Geology and mineral deposits of the Western San Gabriel Mountains, Los Angeles County____ Price $0.60, sales tax $0.02 .62

October. Mineral Resources of the Resting Springs Region, Inyo County. Paleozoic Section in the Nopah and Resting Springs Mountains, Inyo County, California. Native Arsenic from Grass Valley, California____ Price $0.60, sales tax $0.02 .62

Chapters of Report XXXIV, 1938 (quarterly) : titled 'California Journal of Mines and Geology,' containing the following:

**January. Mineral Development and Mining Activity in Southern California during the year 1937. Doing Something About Earthquakes. Gold and Petroleum in California. Gem Minerals of California, Lapidary Art ____ ----

April. Gold Dredging in Shasta, Siskiyou and Trinity Counties; Geology of the Central Santa Monica Mountains; Marketing Mica____ Price $0.60, sales tax $0.02 .62

July. El Dorado County, Mineral High-Lights of California; Strategic Minerals of California; Cyanide Treatment of Gossan at Mountain Copper Co.; Submarine Canyons off the California Coast____ Price $0.60, sales tax $0.02 .62

REPORTS—Continued

Asterisks (**) indicate the publication is out of print. Price (including postage and sales tax)

October, Inyo County, Biennial Report of State Mineralogist, Sulphur Deposits of Inyo County, Geology of the Darwin-Lead Mining District Price $0.60, sales tax $0.02 $0.62

Chapters of Report XXXV, 1939 (quarterly) titled "California Journal of Mines and Geology," containing the following:

January, San Diego County, Geology and Oil Possibilities of Southwestern San Diego Co.; Prospect for 'Minor Metals' and Nonmetallic Minerals; The Right to Mine—Price $0.60, sales tax $0.02 .62

April, Shasta County, Public's Interest in Mine Taxation— Price $0.60, sales tax $0.02 .62

July, Tertiary Formations of Northern Sacramento Valley, California; Geology and Oil Possibilities of Caliente Range, Cuyama Valley and Carrizo Plain, California; Bibliography of the Geology and Mineral Resources of California for the year 1937; the Giant Goose Lake Meteorite from Modoc County, California—Price $0.60, sales tax $0.02 .62

**October, Quicksilver Resources of California; Sulphate Minerals of the Leviathan Sulphur Mine, Alpine County, California—

Reprint from above, Quicksilver Resources of California— Price $0.50, sales tax $0.01 .51

Chapter of Report XXXVI, 1940 (quarterly) titled "California Journal of Mines and Geology," containing the following:

January Current Mining Activity in Southern California; Notes on Beryl with a Qualitative Analysis for Beryllium; Strategic Minerals Investigations Procedure followed by the U. S. Bureau of Mines— Price $0.60, sales tax $0.02 .62

April, Mineral Resources of Mono County; General Geology and Ores of the Blind Spring Hill Mining District, Mono County, California; Short Report on the Geological Formations Encountered in Driving the Mono Craters Tunnel; Methods and Costs of Mining and Concentrating Chromite—Price $0.60, sales tax $0.02 .62

July, Economic Mineral Deposits of the Newberry and Ord Mountains, San Bernardino County; Geology of the Newberry and Ord Mountains, San Bernardino County, California; Notes on the Geology of a Portion of the Calico Mountains, San Bernardino County, California; Study of Chrome Process Aided by Martin Dennis Company— Price $0.60, sales tax $0.02 .62

October, Mineral Resources of the Kernville Quadrangle; Strategic Problems of the Mineral Industry in California; Descriptive Geology of the Kernville Quadrangle, California; Biennial Report of the State Mineralogist; Strategic Tax Exemption; Federal Loans for Strategic Minerals—Price $0.60, sales tax $0.02 .62

Chapters of Report XXXVII, 1941 (quarterly) titled "California Journal of Mines and Geology," containing the following:

January, Mineral Resources of Trinity County; Strategic Minerals Procurement; Geologic Investigation of the Chromite Deposits of California; United States Supreme Court Renders Far-reaching Decision on Power Permits on "Navigable" Streams; Securities and Exchange Commission—Price $0.60, sales tax $0.02 .62

April, Tungsten Resources of California; Geological Progress of State Division of Mines; California Earthquakes of Mission Period, 1769-1838—Price $0.60, sales tax $0.02 .62

July, (Nevada County Report and Maps) Mines and Mineral Resources of Nevada County; Price of Gold—Price $0.60, sales tax $0.02 .62

October, (Humboldt County) Mineral Resources of Humboldt County; Recent Developments in the Tungsten Resources of California; Tin in California—Price $0.60, sales tax $0.02 .62

Chapters of Report XXXVIII, 1942 (quarterly) titled "California Journal of Mines and Geology," containing the following:

January, Mines and Mineral Resources of Sierra County; Chromium— Price $0.60, sales tax $0.02 .62

REPORTS—Continued

Asterisks (**) indicate the publication is out of print. — Price (including postage and sales tax)

April, Mineral Resources of Imperial County (report and map); Geology and Mineral Deposits of the Cargo Muchacho Mountains, Imperial County (map and report); Imperial Carbon Dioxide Gas Field; Legendary "White Metal" and Its "Ore"; Mine Assessment Work Suspended on Claims Within Withdrawn Areas—Price $0.60, sales tax $0.02 — $0.62

July-October, Tungsten. Tabulated list of deposits; Economic Mineral Map No. 4—Tungsten; Geology of Ghost Canyon Deposit, Madera County; Geology of Welsh Deposit, Madera County; Geology of Confidence Mining District Deposits, Tuolumne County; Contact-Metamorphic Rocks of Twin Lakes Region, Fresno County; Coso Hot Springs Geology; Biennial Report of State Mineralogist—Price $1.20, sales tax $0.03 — 1.23

Chapters of Report XXXIX, 1943 (quarterly) titled "California Journal of Mines and Geology" containing the following:

January, Mines and Mineral Resources of Santa Cruz County (report and map); Organization and Service of the Division of Mines; Recent Activity in the Strategic Minerals in the San Francisco, Los Angeles, Sacramento, and Redding Field Districts; Department of Interior Information Service—Price $0.60, sales tax $0.02 — .62

April, Manganese Discovery in San Mateo County; Current Mining Activity in Southern California; Current Notes on Activity in Strategic Minerals, Sacramento Field District; Clerbus-Mae Tungsten Prospect, Trinity County; Mylonites in Eastern San Gabriel Mountains; Geology of Sierra Nevada Northeast of Visalia, Tulare County; Tungsten Deposits Northeast of Visalia, Tulare County; Geology of San Benito Quadrangle (report and map)—Price $0.60, sales tax $0.02 — .62

July, Carbon Dioxide Gas in Mendocino and Northern Sonoma Counties; Current notes on Activity in Strategic Minerals, Redding and Sacramento Field Districts; Crestmore Minerals; The Isometrograph as Developed and Used at New Idria Quicksilver Mine; Notes relating to Sutter (Marysville) Buttes Gas Field; Sillimanite Group of Minerals; New Federal and State Legislation Affecting Mining—Price $0.60, sales tax $0.02 — .62

October, Mines and Mineral Resources of San Bernardino County (report and map); Current Notes on Activity in Strategic Minerals, Sacramento Field District—Price $0.60, sales tax $0.02 — .62

Subscription, $2.00 postpaid in advance

BULLETINS

**Bulletin No. 1. Description of Some Desiccated Human Remains, by Winslow Anderson. 1888, 41 pp., 6 illustrations — ----

**Bulletin No. 2. Methods of Mine Timbering, by W. H. Storms. 1894, 58 pp., 75 illustrations — ----

**Bulletin No. 3. Gas and Petroleum Yielding Formations of Central Valley of California, by W. L. Watts. 1894, 100 pp., 13 illustrations, 4 maps — ----

**Bulletin No. 4. Catalogue of California Fossils, by J. G. Cooper. 1894, 73 pp., 67 illustrations. (Part I was published in the Seventh Annual Report of the State Mineralogist, 1887) — ----

**Bulletin No. 5. The Cyanide Process, 1894, by Dr. A. Scheidel. 140 pp., 46 illustrations — ----

**Bulletin No. 6. California Gold Mill Practices, 1895, by E. B. Preston. 85 pp., 46 illustrations — ----

**Bulletin No. 7. Mineral Production of California, by Counties, for the year 1894, by Charles G. Yale. Tabulated sheet — ----

**Bulletin No. 8. Mineral Production of California, by Counties, for the year 1895, by Charles G. Yale. Tabulated sheet — ----

BULLETINS—Continued

Asterisks (**) indicate the publication is out of print.	Price (including postage and sales tax)
**Bulletin No. 9. Mine Drainage, Pumps, etc., by Hans C. Behr. 1896, 210 pp., 206 illustrations	----
**Bulletin No. 10. A Bibliography Relating to the Geology, Paleontology and Mineral Resources of California, by Anthony W. Vogdes. 1896, 121 pp.	----
**Bulletin No. 11. Oil and Gas Yielding Formations of Los Angeles, Ventura and Santa Barbara Counties, by W. L. Watts. 1897, 94 pp., 6 maps, 31 illustrations	----
**Bulletin No. 12. Mineral Production of California, by Counties, for 1896, by Charles G. Yale. Tabulated sheet	----
**Bulletin No. 13. Mineral Production of California, by Counties, for 1897, by Charles G. Yale. Tabulated sheet	----
**Bulletin No. 14. Mineral Production of California, by Counties, for 1898, by Charles G. Yale	----
**Bulletin No. 15. Map of Oil City Fields, Fresno County, by John H. Means, 1899	----
**Bulletin No. 16. The genesis of Petroleum and Asphaltum in California, by A. S. Cooper. 1899, 39 pp., 29 illustrations	----
**Bulletin No. 17. Mineral Production of California, by Counties, for 1899, by Charles G. Yale. Tabulated sheet	----
**Bulletin No. 18. Mother Lode Region of California, by W. H. Storms, 1900, 154 pp., 49 illustrations	----
**Bulletin No. 19. Oil and Gas Yielding Formations of California, by W. L. Watts. 1900, 236 pp., 60 illustrations, 8 maps	----
**Bulletin No. 20. Synopsis of General Report of State Mining Bureau, by W. L. Watts. 1901, 21 pp. This bulletin contains a brief statement of the progress of the mineral industry in California for the four years ending December, 1899	----
**Bulletin No. 21. Mineral Production of California by Counties, by Charles G. Yale. 1900. Tabulated sheet	----
**Bulletin No. 22. Mineral Production of California for Fourteen Years, by Charles G. Yale. 1900. Tabulated sheet	----
Bulletin No. 23. The Copper Resources of California, by P. C. DuBois, F. M. Anderson, J. H. Tibbits and G. A. Tweedy. 1902, 282 pp., 69 illustrations, 9 maps Price $0.75, sales tax $0.02	$0.77
**Bulletin No. 24. The Saline Deposits of California, by G. E. Bailey. 1902, 216 pp., 99 illustrations, 5 maps	----
**Bulletin No. 25. Mineral Production of California, by Counties, for 1901, by Charles G. Yale. Tabulated sheet	----
**Bulletin No. 26. Mineral Production of California for the Past Fifteen Years, by Charles G. Yale. 1902. Tabulated sheet	----
**Bulletin No. 27. The Quicksilver Resources of California, by William Forstner. 1903, 273 pp., 144 illustrations, 8 maps	----
**Bulletin No. 28. Mineral Production of California for 1902, by Charles G. Yale. Tabulated sheet	----
**Bulletin No. 29. Mineral Production of California for Sixteen Years, by Charles G. Yale. 1903. Tabulated sheet	----
**Bulletin No. 30. Bibliography Relating to the Geology, Palentology and Mineral Resources of California, by A. W. Vogdes. 1903, 290 pp.	----
**Bulletin No. 31. Chemical Analyses of California Petroleum, by H. N. Cooper. 1904. Tabulated sheet	------
**Bulletin No. 32. Production and Use of Petroleum in California by Paul W. Prutzman. 1904, 230 pp., 116 illustrations, 14 maps	----
**Bulletin No. 33. Mineral Production of California, by Counties, for 1903, by Charles G. Yale. Tabulated sheet	----
**Bulletin No. 34. Mineral Production of California for Seventeen Years, by Charles G. Yale. 1904. Tabulated sheet	----
**Bulletin No. 35. Mines and Minerals of California, by Charles G. Yale, 1904, 55 pp., 20 county maps. Relief maps of California	----

BULLETINS—Continued

Asterisks (**) indicate the publication is out of print.

	Price (including postage and sales tax)
**Bulletin No. 36. Gold Dredging in California, by J. E. Doolittle. 1905. 120 pp., 60 illustrations, 3 maps	----
**Bulletin No. 37. Gems, Jewelers' Materials, and Ornamental Stones of California, by George F. Kunz. 1905, 168 pp., 54 illustrations	----
**Bulletin No. 38. Structural and Industrial Materials of California, by Wm. Forstner, T. C. Hopkins, C. Naramore and L. H. Eddy. 1906, 412 pp., 150 illustrations, 1 map	----
**Bulletin No. 39. Mineral Production of California, by Counties, for 1904, by Charles G. Yale. Tabulated sheet	----
**Bulletin No. 40. Mineral Production of California for Eighteen Years, by Charles G. Yale. 1905. Tabulated sheet	----
**Bulletin No. 41. Mines and Minerals of California for 1904, by Charles G. Yale. 1905, 54 pp., 20 county maps	----
**Bulletin No. 42. Mineral Production of California, by Counties, 1905, by Charles G. Yale. Tabulated sheet	----
**Bulletin No. 43. Mineral Production of California for Nineteen Years, by Charles G. Yale. Tabulated sheet	----
**Bulletin No. 44. California Mines and Minerals for 1905, by Charles G. Yale. 1907, 31 pp., 20 county maps	----
**Bulletin No. 45. Auriferous Black Sands of California, by J. A. Edman, 1907. 10 pp.	----
**Bulletin No. 46. General Index of Publications of the California State Mining Bureau, by Charles G. Yale. 1907, 54 pp.	----
**Bulletin No. 47. Mineral Production of California, by Counties, 1906, by Charles G. Yale. Tabulated sheet	----
**Bulletin No. 48. MineralProduction of California for Twenty Years, by Charles G. Yale. 1906	----
**Bulletin No. 49. Mines and Minerals of California for 1906, by Charles G. Yale. 34 pp.	----
Bulletin No. 50. The Copper Resources of California, 1908, by A. Hausmann, J. Kruttschnitt, Jr., W. E. Thorn and J. A. Edman, 366 pp., 74 illustrations. (Revised edition) Price $1.50, sales tax $0.04	$1.54
**Bulletin No. 51. Mineral Production of California, by Counties, 1907, by D. H. Walker. Tabulated sheet	----
**Bulletin No. 52. Mineral Production of California for Twenty-one Years, by D. H. Walker. 1907. Tabulated sheet	----
**Bulletin No. 53. Mineral Production of California for 1907, with County Maps, by D. H. Walker, 62 pp.	----
**Bulletin No. 54. Mineral Production of California, by Counties, by D. H. Walker. 1908. Tabulated sheet	----
**Bulletin No. 55. Mineral Production of California for Twenty-two Years, by D. H. Walker. 1908. Tabulated sheet	----
**Bulletin No. 56. Mineral Production for 1908, with County Maps and Mining Laws of California, by D. H. Walker, 78 pp.	----
**Bulletin No. 57. Gold Dredging in California, by W. B. Winston and Chas. Janin. 1910, 312 pp., 239 illustrations, 10 maps	----
**Bulletin No. 58. Mineral Production of California, by Counties, by D. H. Walker. 1909. Tabulated sheet	----
**Bulletin No. 59. Mineral Production of California for Twenty-three Years, by D. H. Walker. 1900. Tabulated sheet	----
**Bulletin No. 60. Mineral Production for 1909, with County Maps and Mining Laws of California, by D. H. Walker. 94 pp.	----
**Bulletin No. 61. Mineral Production of California, by Counties, for 1910, by D. H. Walker. Tabulated sheet	----
**Bulletin No. 62. Mineral Production of California for Twenty-four Years, by D. H. Walker. 1910. Tabulated sheet	----
**Bulletin No. 63. Petroleum in Southern California, by P. W. Prutzman. 1912, 430 pp., 41 illustrations, 6 maps	----
**Bulletin No. 64. Mineral Production for 1911, by E. S. Boalich. 49 pp.	----
**Bulletin No. 65. Mineral Production for 1912, by E. S. Boalich. 64 pp.	----

BULLETINS—Continued

Asterisks (**) indicate the publication is out of print.	Price (including postage and sales tax)
**Bulletin No. 66. Mining Laws of the United States and California. 1914, 89 pp.	----
**Bulletin No. 67. Minerals of California, by Arthur S. Eakle. 1914, 226 pp.	----
**Bulletin No. 68. Mineral Production for 1913, with County Maps and Mining Laws, by E. S. Boalich. 160 pp.	----
**Bulletin No. 69. Petroleum Industry of California, with Folio of Maps (18 by 22), by R. P. McLaughlin and C. A. Waring. 1914, 519 pp., 13 illustrations, 83 figs. [18 plates in accompanying folio.]	----
**Bulletin No. 70. Mineral Production for 1914, with County Maps and Mining Laws. 184 pp.	----
**Bulletin No. 71. Mineral Production for 1915, with County Maps and Mining Laws, by Walter W. Bradley, 193 pp. 4 illustrations	----
**Bulletin No. 72. The Geoolgic Formations of California, by James Perrin Smith. 1916, 47 pp.	----
**Reconnaissance Geologic Map (of which Bulletin 72 is explanatory), in 23 colors. Scale: 1 inch = 12 miles. Mounted	----
**Bulletin No. 73. First Annual Report of the State Oil and Gas Supervisor of California for the fiscal year 1915-16, by R. P. McLaughlin. 278 pp., 26 illustrations	----
**Bulletin No. 74. Mineral Production of California in 1916, with County Maps, by Walter W. Bradley. 179 pp., 12 illustrations	----
**Bulletin No. 75. United States and California Mining Laws. 1917, 115 pp., paper	----
Bulletin No. 76. Manganese and Chromium in California, by Walter W. Bradley, Emile Huguenin, C. A. Logan, W. B. Tucker and C. A. Waring. 1918, 248 pp., 51 illustrations, 5 maps, paper Price $0.75, sales tax $0.02	$0.77
Bulletin No. 77. Catalogue of Publications of California State Minin Bureau, 1880-1917, by E. S. Boalich. 44 pp., paper	Free
**Bulletin No. 78. Quicksilver Resources of California, with a Section on Metallurgy and Ore-Dressing, by Walter W. Bradley. 1919, 389 pp., 77 photographs and 42 plates (colored and line cuts), cloth	----
Bulletin No. 79. Magnesite in California, by Walter W. Bradley. 1925, 147 pp., 62 photographs, 11 line cuts and maps, cloth Price $1.25, sales tax $0.03	1.28
†Bulletin No. 80. Tungsten. Molybdenum and Vanadium in California. (Not issued—See Apr. 1941 Chap. Report XXXVII.)	
†Bulletin No. 81. Foothill Copper Belt of California. (Not issued.)	
**Bulletin No. 82. Second Annual Report of the State Oil and Gas Supervisor, for the Fiscal Year 1916-1917, by R. P. McLaughlin. 1918, 412 pp., 31 illustrations, cloth	----
**Bulletin No. 83. California Mineral Production for 1917, with County Maps, by Walter W. Bradley. 179 pp., paper	----
**Bulletin No. 84. Third Annual Report of the State Oil and Gas Supervisor, for the Fiscal Year 1917-1918, by R. P. McLaughlin. 1918, 617 pp., 28 illustrations, cloth	----
**Bulletin No. 85. Platinum and Allied Metals in California, by C. A. Logan, 1919. 10 photographs, 4 plates, 120 pp., paper	----
**Bulletin No. 86. California Mineral Production for 1918, with County Maps, by Walter W. Bradley. 1919, 212 pp., paper	----
**Bulletin No. 87. Commercial Minerals of California, with notes on their uses, distribution, properties, ores, field tests and preparation for market, by W. O. Castello. 1920, 124 pp., paper	----
**Bulletin No. 88. California Mineral Production for 1919, with County Maps, by Walter W. Bradley. 1920, 204 pp., paper	----
**Bulletin No. 89. Petroleum Resources of California, with Special Reference to Unproved Areas, by Lawrence Vander Leck. 1921, 12 figures, 6 photographs, 6 maps in pocket, 186 pp., cloth	----

† Not issued.

BULLETINS—Continued

Asterisks (**) indicate the publication is out of print.	Price (including postage and sales tax)
**Bulletin No. 90. California Mineral Production for 1920, with County Maps, by Walter W. Bradley. 1921, 218 pp., paper	----
**Bulletin No. 91. Minerals of California, by Arthur S. Eakle. 1923, 328 pp., cloth	----
**Bulletin No. 92. Gold Placers of California, by Charles S. Haley. 1923, 167 pp., 36 photographs and 7 plates (colored and line cuts, also geological map), cloth	----
**Bulletin No. 93. California Mineral Production for 1922, by Walter W. Bradley. 1923, 188 pp., paper	----
**Bulletin No. 94. California Mineral Production for 1923, by Walter W. Bradley. 1924, 162 pp., paper	----
**Bulletin No. 95. Geology and Ore Deposits of the Randsburg Quadrangle, by Carlton D. Hulin. 1925, 152 pp., 49 photographs, 13 line cuts, 1 colored geologic map, cloth	----
**Bulletin No. 96. California Mineral Production for 1924, by Walter W. Bradley. 1925, 173 pp., paper	----
**Bulletin No. 97. California Mineral Production for 1925, by Walter W. Bradley. 1926, 172 pp., paper	----
**Bulletin No. 98. American Mining Law, by A. H. Ricketts, 1931, 811 pp., flexible leather	----
Bulletin No. 99. Clay Resources and Ceramic Industry of California, by Waldemar Fenn Deitrich. 1928, 383 pp., 70 photographs, 12 line cuts including maps, cloth Price $2.00, sales tax $0.05	$2.05
**Bulletin No. 100. California Mineral Production for 1926, by Walter W. Bradley, 1927, 174 pp., paper	----
**Bulletin No. 101. California Mineral Production for 1927, by Henry H. Symons. 1928, 311 pp., paper	----
**Bulletin No. 102. California Mineral Production for 1928, by Henry H. Symons. 1929, 210 pp., paper	----
Bulletin No. 103. California Mineral Production for 1929, by Henry H. Symons. 1930, 231 pp., paper	----
Bulletin No. 104. Bibliography of the Geology and Mineral Resources of California, to the end of 1930, by Solon Shedd Price $2.50, sales tax $0.06	2.56
Bulletin No. 105. Mineral Production in California for 1930 and Directory of Producers, by Henry H. Symons. 1931	
Bulletin No. 106. Superseded. (See Bulletin No. 120.)	
Bulletin No. 107. Mineral Production in California for 1931 and Directory of Producers, by Henry H. Symons. 1932	
Bulletin No. 108. Mother Lode Gold Belt of California, by Clarence A. Logan, 1934, 240 pp., with geologic and claim maps, cloth Price $2.25, sales tax $0.06	2.31
Bulletin No. 109. California Mineral Production and Directory of Mineral Producers for 1932, by Henry H. Symons, 200 pp., paper	----
Bulletin No. 110. California Mineral Production and Director of Mineral Producers for 1933, by Henry H. Symons, 214 pp., paper	----
Bulletin No. 111. California Mineral Production and Directory of Mineral Producers for 1934, by Henry H. Symons, 334 pp., paper	----
Bulletin No. 112. California Mineral Production and Directory of Mineral Producers for 1935, by Henry H. Symons, 205 pp., paper	----
Bulletin No. 113. Minerals of California, by Adolf Pabst, 1938 Price $1.75, sales tax $0.04	---- 1.79
Bulletin No. 114. California Mineral Production and Directory of Mineral Producers for 1936, by Henry H. Symons, 119 pp., paper	----
Bulletin No. 115. Bibliography of Geology and Mineral Resources of California, 1931 to 1936, by Solon Shedd, Supplementing Bulletin No. 104 Price $1.25, sales tax $0.03	1.28
Bulletin No. 116. California Mineral Production and Directory of Mineral Producers for 1937, by Henry H. Symons. 1938	
Bulletin No. 117. California Mineral Production and Director of Mineral Producers for 1938, by Henry H. Symons. 1939	

BULLETINS—Continued

Asterisks (**) indicate the publication is out of print. Price (including postage and sales tax)

Bulletin No. 118
Geologic Formations and Economic Development of the Oil and Gas Fields of California, by O. P. Jenkins and others
Part One—Development of the Industry, 1940
Part Two—Geology of California and the Occurrence of Oil and Gas, 1941
Part Three—Descriptions of Individual Oil and Gas Fields, 1943
Part Four—Glossaries, Bibliography, and Index, 1943, paper covered separator ____ Four parts $4.00, sales tax $0.10 $4.10
Complete in one volume (cloth bound) ____ Price $6.00, sales tax $0.15 6.15

**Bulletin No. 119. Mineral Production of California for 1939, and Directory of Producers, by Henry H. Symons. 1940 ____ ----

**Bulletin No. 120. Manner of Locating and Holding Mineral Claims in California (with forms), by A. H. Ricketts (revised 1941) Superseded (See Bulletin 127) ____ ----

Bulletin No. 121. Mineral Production of California for 1940, and Directory of Producers, by Henry H. Symons. 1941 ____ Free

Bulletin No. 122. Mineral Production of California for 1941; Directory of Producers and Tables of Total Recorded Production by Counties, by Henry H. Symons, 377 pp., paper ____ Free

Bulletin No. 123. American Mining Law, by A. H. Ricketts, 1943, 1008 pp., cloth ____ Price $5.00, sales tax $0.13 5.13

Bulletin No. 124. Commercial Minerals of California, by George L. Gary. A loose-leaf mimeographed bulletin arranged so that it may be revised and supplemented. 1942 ____ Price $1.00, sales tax $0.03 1.03
With binder ____ Price $1.20, sales tax $0.04 1.24
Revised papers mailed upon receipt of postage

Bulletin No. 125. Manganese in California ____ Price $3.00, sales tax $0.08 3.08

Bulletin No. 126. Mineral Production of California for 1942, and Directory of Producers, by Henry H. Symons, 1943 ____ Price $0.75, sales tax $0.02 .77

Bulletin No. 127. Manner of Locating and Holding Mineral Claims in California (with forms), by A. H. Ricketts (revised 1944) ____ Price $0.25, sales tax $0.01 .26

PRELIMINARY REPORTS

**Preliminary Report No. 1. Notes on Damage by Water in California Oil Fields, December, 1913. By R. P. McLaughlin, 4 pp. ____ ----

Preliminary Report No. 2. Notes on Damage by Water in California Oil Fields, March, 1914. By R. P. McLaughlin, 4 pp. ____ Free

Preliminary Report No. 3. Manganese and Chromium, 1917. By E. S. Boalich. 32 pp. ____ Free

**Preliminary Report No. 4. Tungsten, Molybdenum and Vanadium. By E. S. Boalich and W. O. Castello, 1918. 34 pp. Paper ____ ----

**Preliminary Report No. 5. Antimony, Graphite, Nickel, Potash, Strontium and Tin. By E. S. Boalich and W. O. Castello, 1918. 44 pp. Paper ----

Preliminary Report No. 6. A Review of Mining in California During 1919. By Fletcher Hamilton, 1920. 43 pp. Paper ____ Free

**Preliminary Report No. 7. The Clay Industry in California. By E. S. Boalich, W. O. Castello, E. Huguenin, C. A. Logan, and W. B. Tucker, 1920. 102 pp. 24 illustrations. Paper ____ ----

Preliminary Report No. 8. A Review of Mining in California During 1921, with Notes on the Outlook for 1922. By Fletcher Hamilton, 1922. 68 pp. Paper ____ Free

MINERAL ABSTRACTS

Antimony, 26 pp. ____ Price $0.25, sales tax $0.01 .26
Iron, 52 pp. ____ Price $0.35, sales tax $0.01 .36
Pumice and Volcanic Ash, 50 pp. ____ Price $0.35, sales tax $0.01 .36
Sulphur, 23 pp. ____ Price $0.25, sales tax $0.01 .26
**Tungsten, 33 pp. ____ ----

MISCELLANEOUS PUBLICATIONS

Asterisks (**) indicate the publication is out of print.

	Price (including postage and sales tax)
**First Annual Catalogue of the State Museum of California, being the collection made by the State Mining Bureau during the year ending April 16, 1881. 350 pp.	----
**Catalogue of books, maps, lithographs, photographs, etc., in the library of the State Mining Bureau at San Francisco, May 15, 1884. 19 pp.	----
**Catalogue of the State Museum of California, Volume II, being the collection made by the State Mining Bureau from April 16, 1881, to May 5, 1884. 220 pp.	----
**Catalogue of the State Museum of California, Volume III, being the collection made by the State Mining Bureau from May 15, 1884, to March 31, 1887. 195 pp.	----
Quicksilver Resources of California — Price $0.50, sales tax $0.01	$0.51
**Catalogue of the State Museum of California, Volume IV, being the collection made by the State Mining Bureau from March 30, 1887, to August 20, 1890. 261 pp.	----
**Lakes of California	----
**Drift Mining in California (Reprint)	----
**Catalogue of the Library of the California State Mining Bureau, September 1, 1892. 149 pp.	----
**Catalogue of West North American and Many Foreign Shells with Their Geographical Ranges, by J. G. Cooper. Printed for the State Mining Bureau, April, 1894	----
**Report of the Board of Trustees for the four years ending September, 1900. 15 pp. Paper	----
Reconnaissance of the Colorado Desert Mining District. By Stephen Bowers, 1901. 19 pp. 2 illustrations. Paper	Free
Commercial Mineral Notes. A monthly mimeographed sheet, beginning April, 1923 — (by mail 25¢ annually)	Free

Write for latest revised price list.

MAPS

Register of Mines with Maps

**Register of Mines, with Map, Amador County	----
**Register of Mines, with Map, Butte County	----
**Register of Mines, with Map, Calaveras County	----
**Register of Mines, with Map, El Dorado County	----
**Register of Mines, with Map, Inyo County	----
**Register of Mines, with Map, Kern County	----
**Register of Mines, with Map, Lake County	----
**Register of Mines, with Map, Mariposa County	----
**Register of Mines, with Map, Nevada County	----
**Register of Mines, with Map, Placer County	----
**Register of Mines, with Map, Plumas County	----
**Register of Mines, with Map, San Bernardino County	----
**Register of Mines, with Map, San Diego County	----
Register of Mines, with Map, Santa Barbara County (1906) — Price $0.15, sales tax $0.01	.16
**Register of Mines, with Map, Shasta County	----
**Register of Mines, with Map, Sierra County	----
**Register of Mines, with Map, Siskiyou County	----
**Register of Mines, with Map, Trinity County	----
**Register of Mines, with Map, Tuolumne County	----
Register of Mines, with Map, Yuba County (1905) — Price $0.15, sales tax $0.01	.16
**Register of Oil Wells, with Map, Los Angeles City (1906)	----

Other Maps

Asterisks (**) indicate the publication is out of print.

	Price (including postage and sales tax)
**Map of California, Showing Mineral Deposits (50x60 in.)	----
**Map of Forest Reserves in California	----
**Mineral and Relief Map of California	----
**Map of El Dorado County, Showing Boundaries, National Forests	----
**Map of Madera County, Showing Boundaries, National Forests	----
**Map of Placer County, Showing Boundaries, National Forests	----
**Map of Shasta County, Showing Boundaries, National Forests	----
**Map of Sierra County, Showing Boundaries, National Forests	----
**Map of Siskiyou County, Showing Boundaries, National Forests	----
**Map of Tuolumne County, Showing Boundaries, National Forests	----
Map of Mother Lode Region, Geologic	$0.10
**Map of Desert Region of Southern California	----
Map of Minaret District, Madera County	.10
Map of Copper Deposits in California	Free
**Map of Calaveras County	----
**Map of Plumas County	----
**Map of Trinity County	----
**Map of Tuolumne County	----
**Geographical Map of Inyo County. Scale 1 inch equals 4 miles	----
**Map of California accompanying Bulletin No. 89, showing generalized classification of land with regard to oil possibilities. Map only, without Bulletin	----
**Geologic Map of California, 1916. Scale 1 inch equals 12 miles. Shows railroads, highways, post offices and other towns. Geological details lithographed in 23 colors. Mounted	----
**Unmounted	----
Geologic Map of California, 1938. Scale 8 miles per inch. Lithographed in 80 distinguishing colors and patterns showing geologic units. In 6 sections, each 32 in. x 42 in. Set of 6 sheets, unmounted. Sheets not sold separately — Price $4.00, sales tax $0.10	4.10
**Topographic Map of Sierra Nevada Gold Belt, showing distribution of auriferous gravels, accompanying Bulletin No. 92. In 4 colors	----
Geologic Map of Northern Sierra Nevada, showing Tertiary River Channels and Mother Lode Belt accompanying July-October Chapter of Report XXVIII of the State Mineralogist. (Sold singly) — Price $0.25, sales tax $0.01	.26
Map of Northern California, showing rivers and creeks which produced placer gold in 1932 — Price $0.15, sales tax $0.01	.16
Mother Lode Geologic and claim maps in 5 county sections: El Dorado, Amador, Calaveras, Tuolumne and Mariposa — Price $0.15, sales tax $0.01	.16
**Map of Mariposa County, showing principal gold mines	----
**Geologic Map of Elizabeth Lake Quadrangle, Los Angeles and Kern Counties (accompanying October Chapter of Report XXX), sold separately	----
Map of Western Portion of Siskiyou County Showing Location of Principal Gold Mines (accompanying July Chapter of Report XXXI), sold separately — Price $0.15, sales tax $0.01	.16
Geologic Map of Redding and Weaverville Quadrangles Showing Location of Gold Mines — Price $0.15, sales tax $0.01	.16
Map of Ancient Channel System, Calaveras County Map of Ancient Channels Between San Andreas and Mokelumne Hill Set of 2 — Price $0.25, sales tax $0.01	.26
Minaret District, Madera County	.10
Perris Block Geologic	.10
Plumas County Geologic — Price $0.15, sales tax $0.01	.16
Shasta County — Price $0.15, sales tax $0.01	.16
El Dorado County — Price $0.15, sales tax $0.01	.16
Trinity County, Showing Locations of Principal Mineral Deposits (accompanying Jan. Chapt. of Report XXXVII) — Price $0.15, sales tax $0.01	.16

Other Maps—Continued

Asterisks (**) indicate the publication is out of print.	Price (including postage and sales tax)
Quicksilver deposits, sold in conjunction with Quicksilver Resources of California (reprint) ---- Price $0.50, sales tax $0.01	$0.51
Nevada County (accompanying July Chapter of Report XXXVII) ---- Price $0.15, sales tax $0.01	.16
Grass Valley and Nevada City District claim map ----	.10
Oil and Gas Fields Map ---- Price $1.00, sales tax $0.03	1.03
Chromite deposits ---- Price $0.60, sales tax $0.02	.62
Tungsten deposits, sold in conjunction with July-October 1942 Chapter of Report XXXVIII ---- Price $0.60, sales tax $0.02	.62
Chart of Commercial Minerals of California ----	Free
Imperial County (accompanying April chapter of Report XXXVIII) ----	.10
Index Map of Economic Minerals and Geomorphic Provinces ----	Free
Inyo County (accompanying Oct. chapter of Report XXXIV) ---- Price $0.15, sales tax $0.01	.16
Kernville Quadrangle (accompanying October chapter of Report XXXVI)	.10
Los Angeles County (accompanying July chapter of Report XXXIII) ---- Price $0.15, sales tax $0.01	.16
Manganese deposits ---- Price $0.60, sales tax $0.02	.62
Mono County (accompanying April chapter of Report XXXVI) ----	.10
San Diego County (accompanying January chapter of Report XXXV) ---- Price $0.15, sales tax $0.01	.16
Santa Cruz County (accompanying January chapter of Report XXXIX) ---- Price $0.15, sales tax $0.01	.16
Geologic Map of Western Santa Monica Mountains ----	.10

OIL AND GAS FIELD MAPS

The following maps are on sale at the State Division of Oil and Gas, Ferry Building, San Francisco, and the various branch offices. The maps are revised as development work advances and ownerships change. Price includes postage.

No.		*Price*
1	Sargent, Santa Clara County ----	$0.75
2	Santa Maria, including Cat Canyon—Los Alamos, Santa Barbara County ----	1.25
3	Santa Maria, including Casmalia and Lompoc, Santa Barbara County ----	1.25
4	Brea Olinda and East Coyote, Los Angeles, Orange Counties ----	1.25
6	Salt Lake—Beverly Hills, Los Angeles County ----	1.25
7	Sunset, including San Emidio, Kern County ----	1.25
8	South Midway, including Buena Vista Hills, Kern County ----	1.25
9	North Midway and McKittrick, Kern and San Luis Obispo Counties ----	1.25
10	South Belridge and McKittrick-Temblor oil fields, Kern County ----	1.25
11	Lost Hills and North Belridge, including Antelope Hills, Kern County ----	1.25
12	Devils Den, Kern County ----	1.00
13	Kern River and Kern Front fields, including portion of Poso Creek field, Kern County ----	1.00
14	Coalinga, Jacalitos, and East Coalinga Extension, Fresno County ----	1.50
15	Elk Hills, Kern County ----	1.25
16	Ventura and Rincon, Ventura County ----	1.75
17	Santa Paula-Ojai, including South Mountain, Ventura County ----	1.25
18	Sespe-Piru-Simi, including Bardsdale, Ventura County ----	1.50
18a	Newhall, Aliso Canyon, Newhall-Potrero, Del Valle and Oak Canyon, Los Angeles County ----	1.25
19	Arroyo Grande, San Luis Obispo County ----	1.00
20	Long Beach, Los Angeles County ----	1.75
21B	District 5, boundaries of areas including oil fields, Fresno, Kings and Kern Counties ----	1.00
21C	District 4, boundaries of areas including oil fields, Kern, Kings and Tulare Counties ----	1.25

OIL AND GAS FIELD MAPS—Continued

No.		*Price*
22	District 3, boundaries of areas including oil fields, Santa Barbara County	$0.75
23	District 2, boundaries of areas including oil fields, Ventura County	1.00
24	District 1, boundaries of areas including oil fields, Los Angeles and Orange Counties	1.00
26	Huntington Beach, Orange County	1.50
27	Santa Fe Springs, Los Angeles County	1.25
28	Torrance, Los Angeles County	1.25
28a	Town Lot area, Torrance field, Los Angeles County	.75
29	Dominguez, Los Angeles County	1.00
30	Rosecrans, Los Angeles County	1.25
31	Inglewood, Los Angeles County	1.25
32	Seal Beach, Los Angeles and Orange Counties	1.25
34	Mt. Poso and Poso Creek, Kern County	1.00
35	Round Mountain, Kern County	1.00
36	Kettleman North Dome and Middle Dome, Fresno and Kings Counties	1.50
37	Montebello, Los Angeles County	1.00
38	Whittier, Los Angeles County	1.25
39	West Coyote Oil Field, Los Angeles and Orange Counties	1.25
40	Elwood, Goleta (abandoned), La Goleta (gas), Santa Barbara County	1.25
41	Potrero, Los Angeles County	1.00
42	Playa del Rey, Los Angeles County	1.50
43	Capitan, Santa Barbara County	1.00
44	Mesa, Santa Barbara County	1.50
46	Richfield, Orange County	1.25
48	Mountain View and Edison, Kern County	1.25
49	Fruitvale, Kern County	1.00
50	Wilmington, Los Angeles County	1.25
51	Santa Maria Valley, Santa Barbara County	1.00
52	El Segundo and Lawndale, Los Angeles County	1.50
53	Rio Bravo and Greeley, Kern County	1.00
54	Wasco oil field, Buttonwillow and Semitropic (gas), Kern County	1.25
55	Canal, Canfield Ranch, Coles Levee, Strand, Ten Section, Kern County	1.25
56	Paloma, Kern County	1.25
57	Rio Vista (gas), Sacramento, Solano, and Contra Costa Counties	1.00
58	Trico Gas, Kern, Kings and Tulare Counties	1.00
59	Raisin City, Helm and Riverdale, including Wheatville area, Fresno County	1.25

o

36585 7-44 2M

STATE OF CALIFORNIA
DEPARTMENT OF NATURAL RESOURCES
WARREN T. HANNUM, Director

DIVISION OF MINES
FERRY BUILDING, SAN FRANCISCO

WALTER W. BRADLEY State Mineralogist

Vol. 40 JULY 1944 No. 3

CALIFORNIA JOURNAL

OF

MINES AND GEOLOGY

QUARTERLY CHAPTER

OF

STATE MINERALOGIST'S REPORT XL

38463

DIVISION OF MINES

EXECUTIVE AND TECHNICAL STAFF

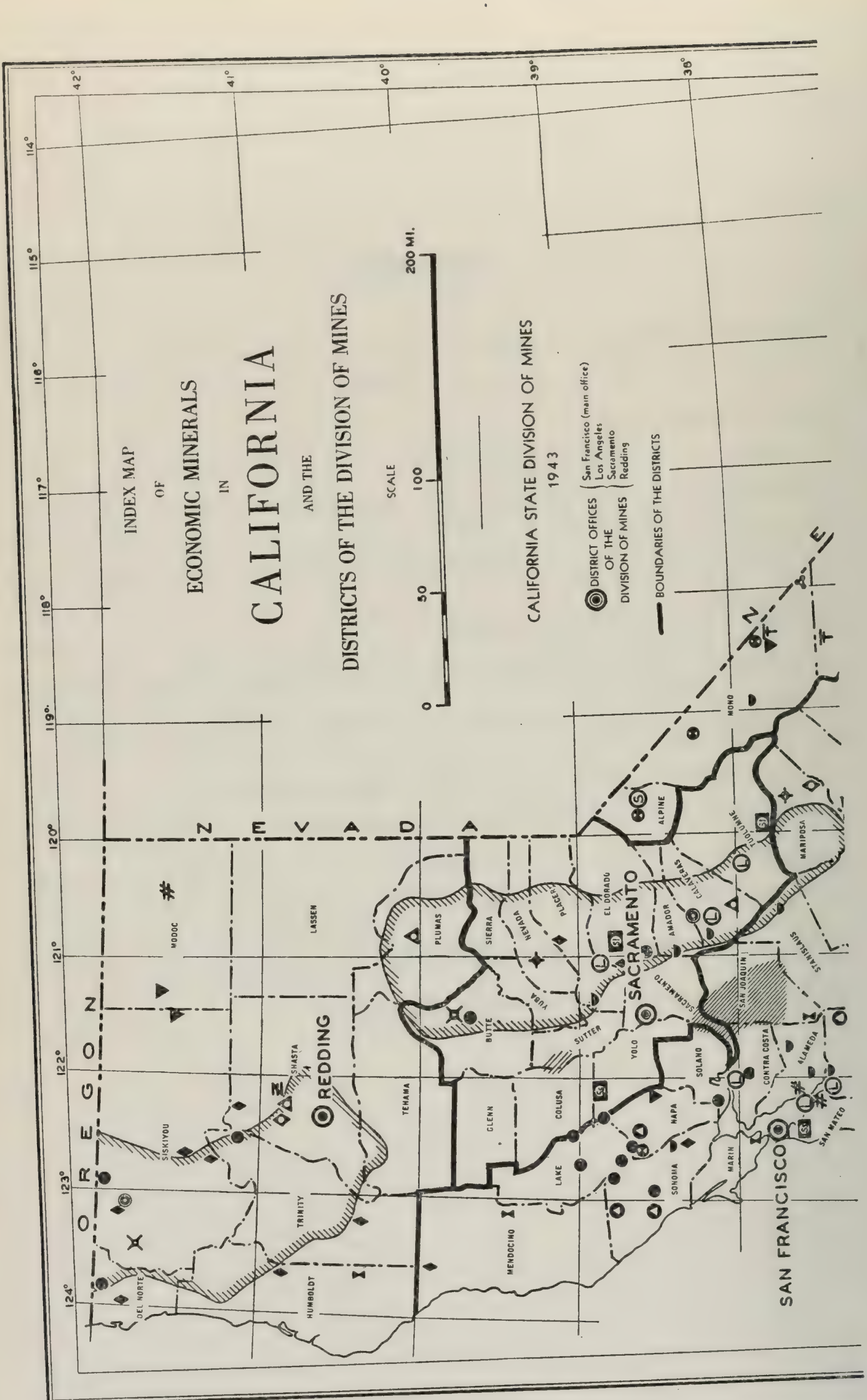
WALTER W. BRADLEY

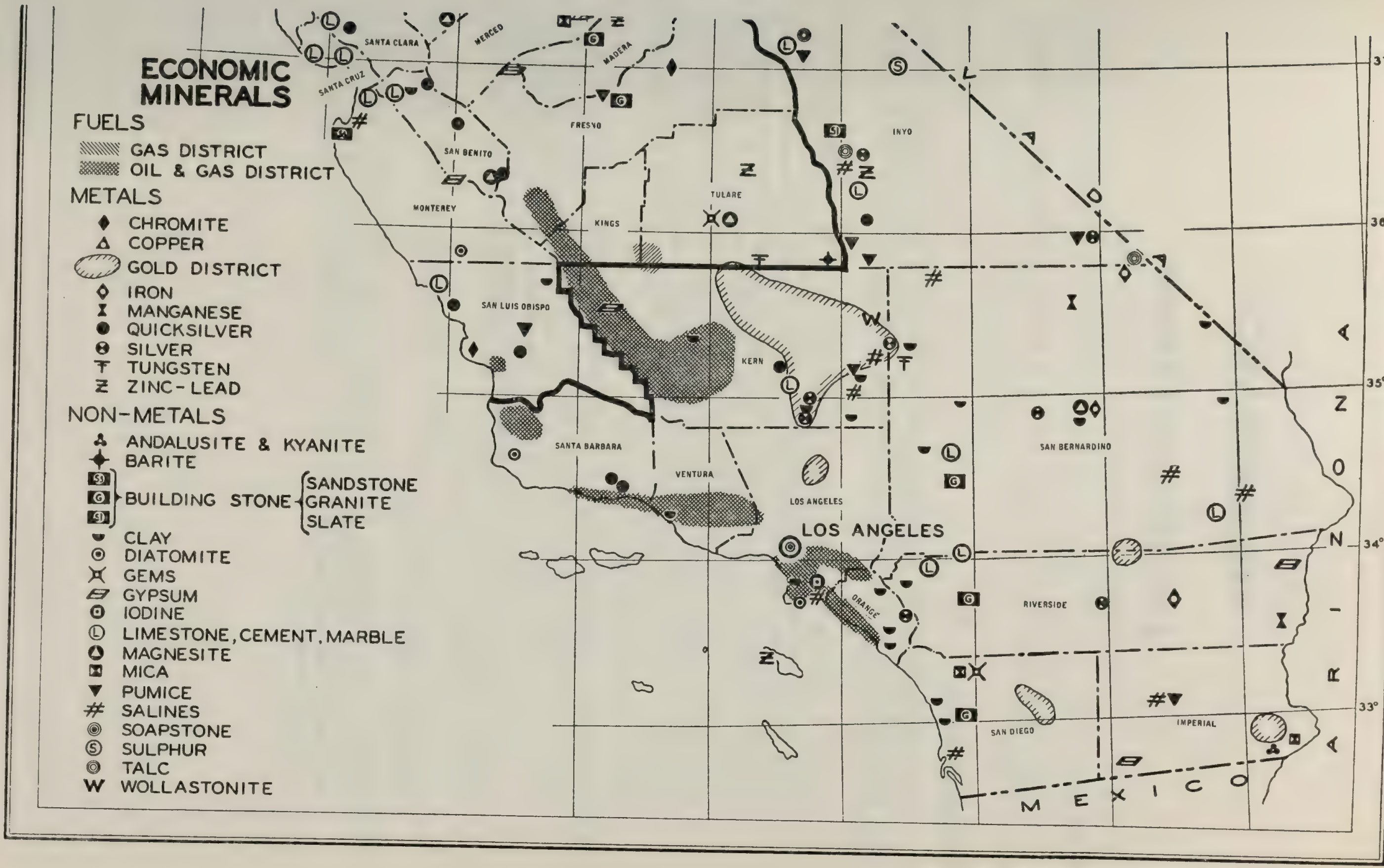
State Mineralogist

OLAF P. JENKINS, Chief Geologist	San Francisco
C. A. LOGAN, District Mining Engineer	Sacramento
W. BURLING TUCKER, District Mining Engineer	Los Angeles
CHAS. V. AVERILL, District Mining Engineer	San Francisco
J. C. O'BRIEN, District Mining Engineer	Redding
REID J. SAMPSON, Assistant District Mining Engineer	Los Angeles
GEORGE L. GARY, Mineral Technologist	San Francisco
JOHN F. BONGARD, Ore-Buyers' Inspector*	San Francisco
HENRY H. SYMONS, Statistician and Curator	San Francisco
JAMES M. LITTLE, Junior Mining Engineer (Librarian)	San Francisco
ELISABETH L. EGENHOFF, Editor, Geologic Branch	San Francisco
FENELON F. DAVIS, Geological Draftsman	San Francisco
MARY H. HELM, Geological Draftsman	San Francisco

* On leave for military service.

CONTENTS


INDEX MAP
OF
ECONOMIC MINERALS
IN
CALIFORNIA
AND THE
DISTRICTS OF THE DIVISION OF MINES
SCALE
0
50
100
200 MI.
CALIFORNIA STATE DIVISION OF MINES
1943
DISTRICT OFFICES OF THE DIVISION OF MINES
San Francisco (main office)
Los Angeles
Sacramento
Redding
BOUNDARIES OF THE DISTRICTS
OREGON
NEVADA
SAN FRANCISCO
SACRAMENTO
REDDING
DEL NORTE
SISKIYOU
MODOC
HUMBOLDT
TRINITY
SHASTA
LASSEN
TEHAMA
PLUMAS
MENDOCINO
GLENN
BUTTE
SIERRA
NEVADA
YUBA
PLACER
LAKE
COLUSA
SUTTER
YOLO
EL DORADO
ALPINE
SONOMA
NAPA
SOLANO
SACRAMENTO
AMADOR
CALAVERAS
TUOLUMNE
MONO
MARIN
CONTRA COSTA
SAN JOAQUIN
STANISLAUS
MARIPOSA
ALAMEDA
SAN MATEO
42°
41°
40°
39°
38°
114°
115°
116°
117°
118°
119°
120°
121°
122°
123°
124°


ECONOMIC MINERALS
FUELS
GAS DISTRICT
OIL & GAS DISTRICT
METALS
CHROMITE
COPPER
GOLD DISTRICT
IRON
MANGANESE
QUICKSILVER
SILVER
TUNGSTEN
ZINC-LEAD
NON-METALS
ANDALUSITE & KYANITE
BARITE
BUILDING STONE
SANDSTONE
GRANITE
SLATE
CLAY
DIATOMITE
GEMS
GYPSUM
IODINE
LIMESTONE, CEMENT, MARBLE
MAGNESITE
MICA
PUMICE
SALINES
SOAPSTONE
SULPHUR
TALC
WOLLASTONITE
SANTA CLARA
MERCED
MADERA
SANTA CRUZ
FRESNO
SAN BENITO
MONTEREY
KINGS
TULARE
INYO
SAN LUIS OBISPO
KERN
SANTA BARBARA
VENTURA
LOS ANGELES
LOS ANGELES
SAN BERNARDINO
ORANGE
RIVERSIDE
SAN DIEGO
IMPERIAL
NEVADA
ARIZONA
MEXICO
37°
36°
35°
34°
33°

ADMINISTRATION

ADMINISTRATIVE REPORT

By Walter W. Bradley, State Mineralogist

Personnel

There have been no personnel changes to be noted during the past three months.

New Publications

Since last noted, the following publications of the Division of Mines have been received from the State Printer, and are now available at the offices of the Division:

CALIFORNIA JOURNAL OF MINES AND GEOLOGY, July 1943, being Chapter 3 of State Mineralogist's Report XXXIX. This chapter contains: *Administrative Report; Carbon dioxide gas occurrences in Mendocino and northern Sonoma Counties; Current notes on activity in the strategic minerals, Sacramento Field District; Current notes on the activity in the strategic minerals, Redding Field District; Crestmore minerals; The isometrograph as developed and used at the New Idria quicksilver mine; Notes relating to Sutter (Marysville) Buttes gas field.* Also special articles on: *The sillimanite group of minerals; New Federal and State legislation affecting mining. Current notes on exhibits,* and *Statistics of mineral production; Laboratory notes.*

BULLETIN 125. MANGANESE IN CALIFORNIA, including *Outline geologic map of California showing locations of manganese properties.* Contains chapters on: *History of the manganese industry; Occurrence and minerals of manganese; Utilization of California manganese ores; Manganese deposits of California—a summary report including tabulated data on manganese properties; Genesis of the manganese deposits of the Coast Ranges; Manganese deposits of the Sierra Nevada, their genesis and metamorphism.*

BULLETIN 126. CALIFORNIA MINERAL PRODUCTION FOR 1942 (and Directory of Mineral Producers).

BULLETIN 127. MANNER OF LOCATING AND HOLDING MINERAL CLAIMS IN CALIFORNIA. A "boiled-down", 35-page edition of the salient features of the American Mining Law prepared from the Division's detailed 1018-page Bulletin 123.

GEOLOGIC BRANCH

CURRENT NOTES

By Olaf P. Jenkins *

In This Issue

Mineralogists will be interested to know that *Minerals of California* is to be revised and completely rewritten by Professors Joseph Murdoch and Robert W. Webb of the University of California at Los Angeles. A progress report of their work is given in this JOURNAL. Contributions to this new bulletin will be greatly appreciated.

The background of the discovery, use, and general appreciation of minerals in California is found in the culture of the Indians. This interesting story is told by anthropologists Robert F. Heizer and Adan E. Treganza in this issue of the JOURNAL. They would appreciate receiving further information from authoritative sources on this subject.

In Preparation

In the next issue (October) of the JOURNAL will be a short paper by Professor A. F. Rogers on *Pellet Phosphorite from Carmel Valley, Monterey County, California.* The United States Geological Survey is also contributing a paper by Cordell Durrell on the *Geology of the Quartz-Crystal Mines near Mokelumne Hill, Calaveras County, California.*

A series of detailed geologic reports on individual iron-ore deposits have been received by the Geologic Branch from the United States Geological Survey for publication in a forthcoming bulletin, *Iron Resources of California.*

---

* Chief Geologist, State Division of Mines.

PROGRESS ON REVISION OF BULLETIN 113, "MINERALS OF CALIFORNIA"

By Joseph Murdoch* and Robert W. Webb*

INTRODUCTION

Revision of Bulletin 113, *Minerals of California,* of the California State Division of Mines, was actively initiated in March 1944, by the writers, under a commission arranged by the Chief Geologist, Dr. Olaf P. Jenkins. A report of progress to date is in order, since the new revision will be prepared with some new objectives.

PLAN OF THE REVISION

The present procedure involves several factors:

(1) A recheck of all present entries, to provide a means of evaluating the accuracy of each. This entails a complete scanning of all geological and mineralogical journals for reference to important occurrences of California minerals. Each entry is being verified by a reference number, including page, to which the reader may refer for the original source of the reported occurrence. Where published reports of occurrences are lacking, specimens in individual or museum collections and personal statements will be employed. Hearsay and word-of-mouth reports not supported by written statements and samples will be separated from verified entries, and recognition given only to occurrences reported with reasonable accuracy. Present entries will be carefully sorted by the above standard.

(2) Additions to the bibliography are being made to include (a) all original references to locality descriptions, (b) all papers on California minerals, including those containing information more or less directly bearing on minerals.

(3) In preparation are brief descriptions of many outstanding mineral localities and ore-producing regions of the State, to include particulars of occurrence, form, and history of the locality.

(4) Organization of the information on mining districts and geographic names is planned so that old localities may be found with greater ease than at present.

(5) Addition of localities described since 1936 will bring the information up-to-date.

It is planned to have a section on the historical and prehistoric use of minerals, if enough material of interest can be assembled, and also a sketch history of the development of mining in the State.

PROGRESS TO DATE

Approximately 10,000 entries have been verified to date by literature checks, and over 2500 titles recorded, by scanning publications in English, and some in other languages. Contact has been made with organizations which may assist in providing accurate information on new and old localities. Individuals will likewise be contacted, although systematic efforts in this direction have not as yet been undertaken. Any information which will assist in a more complete and accurate volume will be gratefully received by the writers, especially accurate information on the locations of deposits which are now ambiguously stated in Bulletin 113.

*Department of Geology, University of California, Los Angeles 24.

MINES AND QUARRIES OF THE INDIANS OF CALIFORNIA

By Robert F. Heizer* and Adan E. Treganza**

OUTLINE OF REPORT

* Former Research Associate in Anthropology, University of California.
** Former Preparator, Museum of Anthropology, University of California.
Manuscript submitted for publication August 21, 1944.

ABSTRACT

Rocks and minerals were important for industrial and ornamental purposes to the California Indians. A total of 142 aboriginal mine or quarry sites has been plotted on a map with appropriate specific information on each locality entered in the text. The following rocks and minerals are treated: obsidian, steatite, pigments (hematite, manganese, limonite, cinnabar), silica minerals (chert, jasper, flint, chalcedony, agatized wood, quartz crystals), asphaltum, clay, magnesite, turquois, chrysocolla, chrysoprase, tourmaline, galena, porphyry, pumice, sandstone, schist, slate, white chalk, and salt.

Considerable attainments in a rude, practical sort of mineralogy and chemistry were part of the Indian's culture. Trading of mineral products was an important economic pursuit, these materials often reaching far distant tribes, though for the most part each tribe used what lithic resources were afforded by its own territory. Mining methods consisted for the most part of breaking down outcrop materials, although in some cases large open-pit workings (as at the San Bernardino County turquois quarries) or tunnels (at the New Almaden cinnabar locality) were made. Very considerable amounts of material were sometimes quarried out, for example at the Borax Lake and St. Helena obsidian quarries and the Santa Catalina Island steatite deposits. The Indian's operations do not appear to have exhausted any orebody of commercial value to whites.

The paper concludes with a list of all rocks and minerals known to have been used by Indians, together with a comparison of California and North American Indian mining with an extensive selected bibliography on aboriginal North American Indian mines and quarries.

INTRODUCTION

Prehistoric exploitation of mineral resources by the Indians of North America made no appreciable impression on the earth's supply. Few of the products (for the most part nonmetallics) quarried by the Indians are of much present-day economic importance. With one or two minor exceptions, none of the North American aborigines smelted ores to extract metals; indeed, the majority of tribes showed a surprising disregard and disinterest in metals which were obtainable in the native state. Instead,

the Indian tribes north of Mexico lived in a technological Stone Age, their material possessions being made chiefly of stone, wood, bone, pottery, and skin. This is especially true for the 103 tribes (speaking 21 mutually unintelligible languages) who lived in the territory now within the boundaries of the State of California. The history of California might have been very different if the Indians had employed native gold and had tapped the rich placer deposits of the Sierra Nevada. The gold rush would have occurred several hundred years earlier, and under the flag of Spain. In sixteenth-century Mexico the rapid development of mining following the Spanish conquest was due largely to exploitation, by European methods and inducements, of mineral localities already known to the native population.

The word "mining" in the present paper will signify exploitation of mineral deposits or orebodies such as cinnabar, hematite, magnesite, or turquois. "Quarrying" will ordinarily refer to the breaking out of massive rock such as steatite, flint, or granite. The two terms are not mutually exclusive, however, since the small-scale outcrop workings are classified in this paper as mines or quarries, as an extreme extension of the normal definition of these terms.

This report is restricted largely to the mining and utilization of stone materials by the Indian tribes of California. The recoverable knowledge on this subject is no doubt only a fraction of what, collectively, the Indians knew, but it is clear that the aborigines made extensive use of the mineral resources of the State.

The authors have attempted to collect whatever information could be supplied by people known to them, as well as the main data from the literature. They wish to thank the following persons for supplying information: Mr. E. Bulmore, Berkeley; Dr. G. F. Carter, Johns Hopkins University; Mr. E. W. Gifford, University of California; Dr. Olaf P. Jenkins, Chief Geologist, California State Division of Mines; Mr. L. L. Loud, University of California; Mr. H. Sharp, Jacumba; Mr. Allyn Smith, Berkeley; Mr. M. Vonsen, Petaluma; Mr. W. Wallace, University of California. Wartime restrictions on leisure time and against travel have prevented an exhaustive search through the literature and check of localities in the field. As this paper is the first attempt to collate scattered data on Indian use of California rocks and minerals, the authors request that any additional information be sent to them at the Department of Anthropology, University of California, Berkeley 4, California.

THE INDIAN AS A MINERALOGIST AND CHEMIST

A large body of traditional physical and chemical knowledge belonged to the aboriginal inhabitants of California. It was rude, simple, and practical, and of the order which characterized the beginnings of our own tradition of science in the Old World in the Neolithic period 10,000 years ago (Browne, 1935). Familiarity with the physical properties (texture, hardness, cleavage, and color) of stones was a necessity to the Indians, and was gained through constant use. A tough dense rock was better suited for a pestle, drill, axe, or hammer, than brittle, glassy obsidian, which, under skillful pressure could be flaked into thin, sharp blades used as knives or arrowheads.

The collections of thousands of stone tools made and used by the primitive peoples of California demonstrate clearly that they always

selected available stone materials which would make the most efficient and enduring implements. For example, steatite (soapstone) was the almost universal material from which smoking pipes were fashioned in California. Steatite, unlike most other rocks, has a low index of thermal expansion and therefore will not break when heated. In addition, it is soft, and the problem of drilling a hole through the long axis of the pipe was a comparatively easy one. To show that the discovery of steatite as a heat-tolerant material was exploited beyond its first application, we may note thin-walled globular bowls (figure 10*e*) of steatite from Santa Barbara in which food was boiled, and flat steatite plates used as drip-pans for grease in the Klamath River country, and for frying-pans in the Santa Barbara Channel area (figure 10*g*). The use of segmented cane (*Phragmites* sp.) for arrowshafts in southern California led to the employment of grooved steatite arrowshaft straighteners (figure 10*d*). The cane joints are crooked and must be straightened in order to produce an arrow of true flight. The stone is heated and the erratic cane joint set in the groove. The heat of the stone relaxes the bent joint, which is straightened by pressing down the ends of the cane. This technique depends basically upon the employment of a stone which can be heated. The Karok Indians of the Klamath River call soapstone *asaxusas,* ''soft rock,'' a term which reveals the tendency on the part of the natives to label rocks descriptively (Harrington, 1932, p. 151).

The Santa Catalina steatite was not all of the same quality. The softer, more micaceous variety was used for globular pots, while the harder, closer-grained (i.e. more dense) and darker variety was used for weights for digging sticks, pipes, and ornaments. No doubt the Gabrieleño Indians knew these two varieties by different names (Schumacher, 1880).

The Chukchansi subtribe of the Yokuts of the lower San Joaquin River ''cooked'' a newly made steatite pot overnight in a fire. This cooking process had the effect of hardening or tempering the pot so that its durability was increased (Gifford, 1932, p. 25).

The Pomo Indians of Clear Lake divide the local obsidian into two types: (1) *batixaga,* ''arrow obsidian,'' which comes from Lower Lake (locality 3, map 1); and (2) *dupa xaga,* ''to cut obsidian,'' which comes from Cole Creek (locality 5, map 1). The first type is used for arrowpoints; the second, which breaks cleanly with sharp edges, finds use as knives or razors (Loeb, 1926, p. 179). The specialized uses of each of these obsidians are thus recognized by the Indian equivalent of mineralogical terms.

Certain tribes of northern California warmed obsidian before flaking it. It is possible that the size, shape, or even ease of flaking, was affected by such warming. One hears stories of Indian arrowpoint chippers who heated their raw material to a high temperature and flaked it by dropping water on it. There is no evidence at all to support these statements which may have a basis in the misinterpretation of the fairly widespread technique of gently warming the flint or obsidian prior to pressure or percussion chipping (cf. Holmes, 1919, p. 364).

Further recognition of mineralogical alteration of rocks is found among the Wintu tribe of the northern Sacramento Valley, who say that they do not quarry obsidian which has been exposed to the sun; the exposed surface is weathered and altered so that it does not flake properly.

(Fowke, 1896, p. 173.) The alteration, however, is probably caused by other factors in addition to exposure to the sun (Dubois, 1935, p. 127). Similarly, the Karok Indians recognize that the greenish serpentine from one deposit (locality 3, map 2) ''is not much good for making pipe bowls since it will soon crack when it gets hot'' (Harrington, 1932, p. 153).

It was the practice among southern California Indian potters to add crushed grit temper (granite was commonly used) to the clay so that the pot would not crack when fired (M. J. Rogers, 1936). The discovery of at least one clay deposit in the State (locality 13, map 5) that produces a clay to which no tempering material need be added, may be credited to the Indians (Schumacher, 1880, pp. 521-523).

The Indian, no doubt, was faced often with the problem (which we may liken to our own scientific curiosity) of explaining geological and mineralogical phenomena. Thus, the Clear Lake Pomo account for the exfoliated flakes of obsidian scattered on Mount Konocti by a myth in which ''Obsidian Man'' caught in the brush, fell in his struggles to free himself, and broke into thousands of pieces which are now represented by the scattered fragments of volcanic glass on the mountain slopes (Barrett, 1933).

The religious attitude of the Indian must also be taken into account in assessing his knowledge of mineralogy. For example, although obsidian was very widely used in California, it was sometimes considered extremely poisonous. The origin of this belief is not known, but perhaps the effectiveness of obsidian as a material to tip war and hunting arrows accounts for its reputed lethal qualities. Among the Western Achomawi of Modoc County, the chips struck off a block of obsidian were carefully inspected by the arrowpoint maker, who judged whether or not they were poisonous. One chip he might consider poisonous and the next flake not poisonous. As he splits the flakes off he examines them and says ''This for grizzly bear, this for coyote, this for war, etc., and these pieces he keeps'' (Voegelin, 1943, p. 191).

The peculiar optical qualities of quartz crystal were appreciated by the California Indians, and nearly every tribe believed the crystals had magical significance. The Yana Indians of Deer Creek used them as luck charms; elsewhere they were used in curing ceremonies.

The chemical processes employed by the California Indians appear to have been largely limited to simple application of three techniques: (1) evaporation by boiling, baking, or exposure to open air; (2) leaching with water percolation; and (3) oxidation through action of fire. The Kamia of the Imperial Valley leached the salt-impregnated earth of the Salton Sink (locality 2, map 6) and crystallized the salt out by boiling (Gifford, 1931, pp. 24-25). The Stonyford salt seepage (locality 3, map 6) yields salt crystals which are left, after evaporation, on the surface of the ground. The Indians scraped up these crystals during the warm summer, stored them in the crude state, and later refined them by dissolving them in water, then recrystallizing by evaporation the decanted salt solution (Barrett, 1908, pp. 240-244).

The Paiute Indians of Surprise Valley dug a soft brownish-tan chalk rock from a deposit on Bidwell Mountain (locality 5, map 6). This was crushed, soaked in water, and drained, the soluble brown coloration being leached out in the soaking process. It then appeared white, and was used for face paint (Kelly, 1932, p. 116).

The Cocopa at their manganese quarry (locality 2, map 3), which they called *Kwinyilwawa,* or "black place," burned chunks of manganese, which could then be easily broken and pulverized into powder for black face paint. At their hematite quarry (locality 3, map 3), called *Akwurawawa,* "red place," a hole was dug in the quarry and a fire built in the hole. The fire altered the dull reddish hematite to a bright red product, which was dug out and put in a pot, where the salt was leached out and the mineral softened so it could be easily pulverized (Gifford, 1933, p. 278). A similar technique was employed by the Surprise Valley Paiute, who put dull red hematite in a hole in a rock and kindled a fire on top. After the coals were raked off and the ochre had cooled, it turned a brick red (Kelly, 1932, p. 116).

In the area north of San Francisco Bay and west of the Sierra Nevada, it was a common culinary practice to mix ferruginous clay with acorn meal to bake native bread. Acorns contain a high percentage of tannic acid which is generally leached out by water percolation before the acorn meal is boiled as mush and eaten. Chesnut cites one analysis of unleached acorn meal which contained 6.63 percent tannic acid. The purpose of the clay mixture was to convert the tannic acid remaining in the meal into an insoluble compound formed at the baking temperature, under influence of air and moisture, by the action of the tannin of the acorn meal with the iron oxide contained in the clay. The Pomo Indians of Potter Valley call this red clay *masil* and translate the term as "Indian baking powder" (Chesnut, 1902, pp. 338-339; Gifford, 1936, p. 90; Hudson, 1900). A clay sample analyzed by Chesnut contained 10 percent FeO_2 by weight.

Mineral springs were used by the California Indians as we use them today. The Eastern Pomo of Upper Clear Lake knew that Highland Springs (now a health resort) near the headwaters of Adobe Creek possessed medicinal qualities. Tribal members afflicted with certain ailments camped at places near the springs, and drank and bathed in the waters (Barrett, 1908, p. 203). Skaggs Springs, called *Kahowani,* "water hot" (Barrett, 1908, p. 220), Calistoga Hot Springs (Powers, 1877, p. 196), and Pluton Geysers in Sonoma County (Powers, 1877, pp. 22, 203) were used in the same way.

The following hot mineral springs are listed by Waring (1915, pp. 45, 56, 58, 146) as used by the Indians: Jacumba Hot Springs, San Diego County; Warner's Hot Springs, San Diego County; Slates Hot Springs, Monterey County; Tassajara Hot Springs, Monterey County; Casa Diablo Hot Springs, Mono County. Two carbonated springs were known according to Waring (1915, pp. 177, 230): Witter Medical Springs, Lake County, and Mount Ida Spring, Butte County. Sulphur Springs in the Santa Susanna Mountains, Los Angeles County were known to Indians (Waring, 1915, p. 280), and four artesian springs in Riverside County (Toro, Alamo Bonito, Agua Dulce, and Figtree John Springs) were sites of Cahuilla Indian settlements (Waring, 1915, p. 314; Strong, 1929, pp. 147, 185).

The curious Indian custom of burying the dead in hot springs was practiced by the Paiute of northeastern California. In the collections of the University of California are human bones from a hot spring near Cedarville, Modoc County. These bones are heavily impregnated with lime and cinnabar, this last mineral apparently being in solution in the

water. Descriptions of hot-spring burials in this area are to be found in the accounts of Delano (1849) and John Work (1832).

THE INDIAN AS A GEOLOGIST

The California Indian's explanation of such outstanding natural phenomena as earthquakes, and physiographic features like the Sierra Nevada, Yosemite Valley, Salton Sea, and San Francisco Bay, was traditional or mythical. He attributed present-day physiographic features to the actions and feats of mythical animals possessing unlimited powers and endowed with human thought and speech. The interesting point is, however, that the Indians, like ourselves, had an innate desire to explain how the world came to be as it is. Their explanation is to them as completely rational as ours is to us.

The Cahuilla Indians of southern California tell this story of the origin of ancient Lake Cahuilla:

> "Then the water from the south began to rise and all the people moved ahead of the water toward Palm Springs. They settled near Kavinic, where the water did not reach. Then the water began to go back, gradually at first and sometimes rising again." (Strong, 1929, pp. 86-87.)

This myth agrees fairly well with the accepted geologic history of ancient Lake Cahuilla, and may conceivably reflect some Indian memory in tradition of the terminal pluvial fluctuations of the water body; or, more probably, it may be simply a theoretic explanation for the clearly marked ancient beach lines in this desert area.

The Yokuts tribe of Kings River tell the following myth of the origin of the Sierra Nevada and Coast Ranges. Hawk and Crow gathered earth and began to build mountains, starting at Tehachapi Pass, Hawk making the Sierras and Crow the Coast Ranges. After many years they met at Mt. Shasta, and, when they compared their labors, found Crow's mountains were the largest. Hawk claimed Crow had been stealing dirt from his beak, which was true; so Hawk chewed some tobacco and became very wise, and seized the mountains and turned them around. In this way the fact that the Sierra Nevada is larger than the Coast Ranges is explained (Powers, 1877, p. 383).

California Indians all knew what earthquakes feel like, and had explanations for the terrifying manifestations, which they believed to be caused by giants dwelling within the earth. The Southern Diegueño believe a blind man causes quakes; that if he were to roll over quickly, the earth would turn over. But he rolls just a little, and so causes only tremors (Spier, 1920, p. 329). The giant who moves in the earth is the common Indian explanation for earthquakes, as shown by the accounts of the 1906 earthquake collected by S. A. Barrett (1906, pp. 324-325) and A. L. Kroeber (1906, pp. 322-323).

Other legends explaining natural phenomena are the Wintu Indian myth concerning the origins of Glass Mountain in Modoc County, and obsidian (Dubois and Demetracoupoulou, 1931, pp. 306-307); the myth accounting for the origin of San Francisco Bay (A. S. Taylor, 1860, 1861); and the Miwok legends concerning the origin of Yosemite Valley.

THE INDIAN AS A PROSPECTOR

The fact that at least 131 mine or quarry localities were known to the California Indians is sufficient proof of the efficiency of their prospecting.

The primitive California Indians were continually foraging over the countryside in search of food, firewood, and raw materials with which to form their tools and implements. Each tribe, as a rule, occupied a restricted territory whose boundaries were rarely trespassed by neighbors. To do so without permission was a certain cause for war. These limitations of exploitable area had a number of interesting effects; primarily this restriction led to the development of a system of conservation of natural resources (MacLeod, 1936).

Each local Indian group knew every rock outcrop within its territory, and if any stone was of a variety which lent itself to making implements, they used it. Actual prospecting, where the Indian would set out blindly on a search to locate a specific stone material, probably was unknown. Their prospecting was limited to accidental discovery of surface exposures while hunting, gathering food, or moving across country to another village. Mines and quarries seem universally to have belonged to the group and not to an individual, even though the individual discovered the site by himself. This is completely contrary to our own system of ownership, which stimulates, by expectation of economic gain, the discovery and development of ore deposits.

SOCIAL AND ECONOMIC ASPECTS OF ABORIGINAL MINES AND QUARRIES

Trade

The most important function of Indian mines and quarries was to supply materials for the implements and tools to be used to secure subsistence (stone points for war or hunting weapons, mortars or metates for grinding seeds, sling stones, chipped knives for meat cutting), or maintain life's necessities (house-building, skin-dressing, clothing) or as luxuries (decorative or ceremonial objects).

It was only when the local group's needs were satisfied and a surplus of raw material was available that intertribal commodity exchange was possible. Although a certain stone may be used for implements or ornaments by an Indian tribe, or may turn up in an archaeological site, it need not necessarily be of local occurrence. Usually native manufactures are of local materials, but intertribal barter of goods and even long-range trading are not out of the ordinary (cf. Heizer, 1941; Ball, 1941, pp. 16-19). Stefansson noted that the Arctic Eskimo made boat trips of 400 miles to get flint from the quarries at Fort Good Hope. Catlinite (a red clay stone) [1] from Minnesota reached New York and Georgia through native trade channels, and the Mound Builders of the lower Mississippi drainage used quantities of obsidian which came from Yellowstone National Park, some 1500 miles distant. Turquois from New Mexico (and perhaps even from southern California localities) reached the Valley of Mexico, where it was used by the Aztecs. The Walla Walla Indians of the Columbia River came south to obtain the brilliant cinnabar from the New Almaden outcrop near San Jose. These are admittedly excep-

[1] Catlinite, a soft argillaceous clay that hardens on drying has the following composition: silica, 48.20; alumina, 28.20; ferric oxide, 5.00; carbonate of lime, 2.60; manganous oxide, 0.60; magnesia, 6.00; water, 8.40; loss, 1.00 percent. (After Holmes, 1919, p. 253.)

tional examples of far trade, and it was the rule for Indians to use materials which occurred within their own boundaries or within those of adjoining friendly tribes. Simple needs which were easily satisfied, cross-country transport limited to back-packing, a simply developed economic system, and intertribal linguistic difficulties had the cumulative effect of discouraging the development of a true system of international trade. Barter of one type of goods for another between units of one tribe or between friendly neighboring tribes was common, and it was the exception in native California for a stone material to be traded farther than 100 or 150 miles from its source. The Masut group of the Pomo tribe living around Calpella made the 50-mile trip to Clear Lake to secure raw magnesite and obsidian from the quarries owned by the other Pomo groups. They had to ask permission to quarry the stone, but did not pay for the privilege. Groups that could not come in person to quarry the stone might secure obsidian, soapstone, chert, hematite, or other desired substances in exchange for food, tanned skins, or manufactured items such as bows, arrows, baskets, or shell ornaments (Loeb, 1932, p. 88; Pope, 1918, p. 116). Finished articles and implements such as magnesite cylinders, obsidian arrowheads, soapstone arrowshaft straighteners and cooking pots, and ground hematite paint, were often traded to neighboring tribes in exchange for unfinished raw materials or manufactured articles. In 1939 the University of California archaeological excavations at one site on Drakes Bay, Marin County, produced 20 vesicular basalt mortars of the type shown in figure 9*a*, which range in weight from 20 to 125 pounds. Each of these pieces must have been carried to the spot from not less than 25 miles away, no mean task for the slightly built, barefoot natives. Stone is completely lacking in the alluvial deposits of the valley floodplain of the Sacramento and San Joaquin delta region. Each stone found in the habitation mounds has been imported from outside. Similarly, in the Gran Chaco of South America, stone was lacking and had to be imported by the natives. E. Nordenskiöld, the Swedish anthropologist, tells how the Chaco natives who accompanied him on a long trip outside the area began filling their pockets with the first stones they saw, deeming them valuable and unique because they were so rare in their home surroundings. The situation was hardly so special in the central California delta, since the Indians could visit the nearby Sierra Nevada or Coast Ranges, but even to these natives stone doubtless had a higher value than to Indians living in a region where rocks were abundant. At least two successful attempts to find substitutes for stone implements were made in the delta region: (1) small balls of baked clay half the size of a fist, which were used for stone-boiling; and (2) seed-grinding mortars made of wood instead of stone. Thus substitutes for stone eliminated the inconvenience and practical difficulty of securing distant, heavy stone mortars and stone cobbles for cooking (Heizer, 1937).

Ownership

So far as we know there was no private, individual ownership of mine or quarry sites by the Indians. Rather these places were considered property of the group, in which everyone was allowed to share. The Indian's life, however, was not one of communal ownership, since such property as acorn-bearing trees, fishing spots, fish-spearing dams, grass-

seed plots, and deer trails were often owned privately. The position of tribal chief normally did not carry with it special economic prerogatives, though a man might become chief because of his accumulated wealth. Mine and quarry sites in native California were national resources which were available to any or all tribal members who shared in possession of such sites. Advantage to the individual under such an organization would come through his special ability to produce finished or manufactured articles from a particular stone material.

Evidence of the rude beginnings of a special class, social as well as economic, is found in the artisans of the Pomo, who manufactured obsidian arrowpoints, wooden bows, shell wampum, and chert drills. Among the more highly advanced Chumash and Gabrieleño of the Santa Barbara—Los Angeles—Channel Islands region there was a similar development for makers of plank canoes and soapstone bowls had become highly skilled artisans, whose livelihood was largely derived from their work.

Thus, economic advantage did not result from owning a quarry site itself, but rather from the manufacture of finished articles from the quarry product, since any individual in the tribe was free to make use of the raw material which he collected at the quarry. Rarely, if ever, did a tribe establish a rigid monopoly on a certain material, even though this could have been done by refusing access to the source. The Pomo who controlled the excellent Lake County obsidian quarries allowed any Pomo-speaking group and even alien tribes (the Long Valley Wintun and the Coyote Valley Miwok) to visit the quarries and secure implement material. The case is less clear for the Cache Creek magnesite deposit (locality 1, map 6), over which the local Pomo apparently exercised rather strict monopolistic control.

When a neighboring group did not recognize the ownership of a salt or obsidian quarry and was apprehended in the attempt to steal, warfare was the result. The famed Pomo Salt Wars (Kroeber, 1925, p. 236; Loeb, 1926, p. 174; Stewart, 1943, pp. 39, 43) were caused by the unsuccessful attempt of the Potter Valley Pomo to take salt from the Stonyford people without asking permission or giving gifts for the privilege. Efforts of the San Joaquin Yokuts to take cinnabar from the New Almaden mine resulted in battles between the Costanoan owners and the valley tribe. Conflicting claims of ownership of quarries which lay near the boundary division of two tribes were also the cause of contention. The Kato and Yuki both claimed the Black Rock obsidian deposit (locality 23, map 1), and the disagreement caused open warfare between the two tribes (Kroeber, 1928). The Modoc and Achomawi both claimed the Sugar Hill obsidian quarry (locality 8, map 1), and war resulted when the two tribes came into contact (de Angulo and Freeland, 1929, p. 315; Kelly, 1932, p. 141, fn. 157).

Mining Laws

The Indians probably had no particular "mining code" as such, although one principle of Indian philosophy which ran through everything was applied to the use of mines and quarries; this principle is the conservation of natural resources (MacLeod, 1936). Thus the Maidu flint miner at Table Mountain (locality 1, map 4) was prohibited from taking away more flint than he could detach with one blow of his stone hammer. (Dixon, 1905, p. 132.)

In the eatsern United States, certain quarry sites (for example the catlinite quarry of Minnesota and Wisconsin, the Yellowstone obsidian cliff locality, and the Flint Ridge quarries of Ohio) were recognized by all natives as neutral ground where tribes which were bitter enemies could meet but not fight. The concept and practice of neutral ground also obtained in California at the Stonyford salt seepage and the obsidian quarries of Clear Lake where any hostile group could meet another but trouble was forbidden. The theory of neutral ground, found widely throughout the world, is a very interesting one. It works in practice through common consent, for mutual benefit, since it is doubtful that any actual enforcement means guarantee its observance.

MINING METHODS AND TOOLS

Intensive mining operations, in which systematic, large-scale, and continuous exploitation of a localized mineral body or rock deposit was the sole aim, did not occur in Indian California in pre-Spanish times. The only possible exception is the turquois mining area of San Bernardino County where very extensive workings are known. As there is no clear evidence of permanent occupation by the Puebloan peoples who came from the south to mine this turquois, it is assumed that they worked seasonally and perhaps at intervals of several years. Many native mines and quarry sites in California seem to have been worked over a long period of time by different groups or individuals who needed the specific material at the moment. Examples of these sites are the soapstone quarries on Santa Catalina Island, the cinnabar paint mine of New Almaden, the Glass Mountain obsidian quarries in Modoc County, and the Stonyford salt seepage. There is no evidence that any tribe had evolved a special class of miners whose sole job was the production of raw material. The absence of such occupational groups can not be explained on the grounds that the California Indians were culturally incapable of such development. A relatively small Indian population (total for the State in 1770 estimated at 133,000, with a density of about 1 person per square mile) could not have overtaxed the abundant stone resources of the State. There is some evidence that in a few tribes there were specialists who devoted most of their time to the production of finished stone articles, but these were individual artists and not an economic group. The Pomo recognized flint drill-makers, shell wampum drillers, and obsidian chippers, as artisans who were known as *dawi xaga duyi gauk,* "drill flint make person"; *ghal dawi xale gauk,* "wampum drill person"; and *ce emai tsu donta,* "bow arrow maker." Among the Santa Catalina Gabrieleño it seems probable that certain individuals devoted much of their time to making finished soapstone pots. There were no large-scale systematically organized, continuous mining or quarrying operations by the California Indians. The total amount of mining activity was large, but divided among a multitude of independent, small-scale mining and quarrying ventures.

Perhaps the most extensive aboriginal quarry workings in California are the turquois mines of San Bernardino County (localities 1-4, map 6). Since these mines were worked by Puebloan peoples from Arizona and New Mexico, who are known to have been excellent and industrious miners in their homeland (cf. Bartlett, 1935; Hack, 1942; Harrington, 1925, 1926; Morris, 1928; Blake, 1899) the San Bernardino County workings constitute a special case of aboriginal California mining. Exposed tur-

quois veins were followed to depth (12 feet in some cases) in open pits by breaking and crushing the waste mass with hafted stone axes and hammers (fig. 4) and throwing the muck out with a hand scoop made from a tortoise carapace or an animal shoulder blade shovel. Heavy stone pointed picks (fig. 3) weighing up to eight pounds were employed to break out the rock, and there is some indirect evidence that wedges were also used. No signs of the fire-and-water method of breaking rock was found here, but there is evidence of its use in the Arizona-New Mexico region from whence the miners journeyed. When the turquois vein thinned out the pit was abandoned. If the pit got too deep and the amount of labor required to carry out the waste rock became inordinate, it was left for another more easily worked.

Steatite was quarried in considerable quantity at Pots Valley on Santa Catalina Island (locality 1, map 2). This material served predominantly for globular vessels, and the Indians ingeniously worked out the exterior form while the base of the vessel was still attached to the bedrock. The mass was broken off at the base and was then ready for excavation of the interior and smoothing of the sides. This same technique was used at steatite quarries near Providence, Rhode Island, in Virginia, the District of Columbia, and on the Klamath River in northwestern California. Ball (1941, p. 48) notes that this technique was also known to the Scandinavians of Norway and Sweden in Viking times, and to their northern neighbors, the Laplanders. Hard slate chisels (fig. 3*e*) hafted hammers of stone, quartzite and granite (?) picks (fig. 3*a-d*), and quartzite scrapers (fig. 3) were used to quarry the Catalina soapstone. Some of the Indian workings are 15 feet in diameter and 5 feet deep (Schumacher, 1879; Holmes, 1902, pp. 183-184). Schumacher states that at the southeastern end of Santa Catalina Island in an area of about 2 square miles he counted not less than 300 quarry pits (Schumacher, 1878).

Another steatite quarry of some size occurs near Lindsay, Tulare County (locality 5, map 1). The outcrop consists of vertical tilted soapstone sheets which were broken down by heavy stone picks. Shallow depressions near the outcrop indicate that the Indian went to some depth in order to obtain unweathered chunks.

The New Almaden cinnabar deposit was the site of an Indian mine which, although a small-scale venture, had a fairly long tunnel, in which a man could work with comfort. We have two early accounts concerning this tunnel (Lord, 1866, vol. I, p. 209; Downer, 1854) wherein estimates of its length are given as 100 feet and 50 or 60 feet. The deposit of cinnabar, which the Indians used for red paint, was being worked in 1800, and it is probable that the site was known centuries before this time. The presence of human skeletons and rude stone mining tools at the tunnel's working face suggest abandonment after a cave-in. Taylor's statement that as late as 1841 or 1842 the Santa Clara Mission Indians were collecting cinnabar here might roughly date the skeletons and cave-in. Rounded stream pebbles, which probably served as hammers, are mentioned as the mining tools, but there were undoubtedly other types used as well, such as picks and mauls. Torches, too, were probably used, since a small, long tunnel would be too dark inside to see to work.

The only statement on record of the use of fire for quarrying refers to the northern Sacramento Valley Wintu who split off blocks of obsidian at Glass Mountain (locality 7, map 1) by building a fire against the rock

(Dubois, 1935, p. 127). Probably other California tribes used the fire-breaking technique since it is a widely known method among North American Indians.

The flint mine of the Maidu Indians on or near Table Mountain (locality 1, map 4) is described as having a very small opening, but the interior was such that a man could stand upright. This working, like the New Almaden tunnel, may be classed as a mine in the specific sense of the word.

There are numerous instances of Indian operations to obtain subsurface, unweathered material, but these are for the most part only shallow pits.

Not always were massive deposits selected for quarrying, judging from the wide use of float material and gravel deposits. In the Mojave Desert, particularly between Barstow and Crucero where chert and jasper boulders are found, the entire exposed gravel strata show evidence of picking over by Indians, presumably over a long period of time (G. F. Carter, personal observation).

It may be of interest to note here the practice of excavation of deep water wells by the natives of southern California. These data demonstrate that the Indians were capable of large-scale earth removal, and if they had so desired, could have applied the technique to mining operations. Wells were dug by means of a mesquite wood shovel and the earth removed by baskets. In form they consisted of a sloping trench with steps measuring 50 to 75 feet long and up to 25 feet in depth. At the end of the trench was the well, a circular pit some 15 feet in diameter and 25 to 30 feet deep, whose sides were funnelled out towards the top so that the earth did not slide off the sides and fill the well. The Kamia of Imperial Valley and Cahuilla of Coachella Valley were the chief well excavators of southern California. (Anonymous, 1939; Baldwin, 1938; Barrows, 1900; Gifford, 1931, p. 9; Gray, 1873, p. 229; Hilton, 1936; Strong, 1929, p. 43; Walker, 1938).

DESCRIPTION OF MINE AND QUARRY SITES

Obsidian

(Map 1)

Every California Indian was familiar with obsidian, or volcanic glass. It was universally, though not exclusively, employed in the manufacture of chipped arrow and spear points for use in war and hunting. It is a substance particularly amenable to controlled flaking in the production of delicate light-weight arrowpoints (see fig. 11).

Certain obsidian deposits were the major source of supply for a number of tribes in the vicinity. Thus it is stated Sugar Hill or Glass Mountain in Modoc County was the destination of parties of most of the tribes of northern California who each year made the journey in summer from their home territory to secure a quantity of this useful obsidian. The Wintu of McCloud River also used the Glass Mountain obsidian, two or three men making the two- or three-day trip to the northeast. These men fasted through the duration of their journey since the act of obtaining obsidian was in the nature of a semireligious quest (Dubois, 1935, p. 127; Voegelin, 1942, p. 191). It is this religious aspect, which in the Indian's mind is an integral, inseparable, and necessary part of the whole, that serves to set apart their and our patterns of culture.

Perhaps the largest flaked obsidian blades in the world were produced by the California Indians. Leaf-shaped specimens measuring over three feet long have found their way into collections of Indian artifacts (Rust, 1905). Smaller blades up to two feet in length were objects of wealth and ceremonial display in northwestern California. The Indians held them to be so valuable that no price was ever set upon them (Kroeber, 1925, p. 26; Rust, 1905).

Locality 1: On the Southern Pacific Railway about seven miles southeast of Santa Rosa, Sonoma County.

L. L. Loud, who furnished the data on this quarry, states that two old quarry depressions are clearly visible in the obsidian outcrop. An area of about two acres surrounding the quarry is thickly scattered with worked material, and we may conclude from this that the Indians roughed out blanks on the spot, rather than transport unworked chunks of obsidian from which so much wastage would be derived.

Locality 2: East side of Napa River 2½ miles northwest of St. Helena, Napa County.

The quarry and workshop area lies along the highway called the "Silverado Trail" (see fig. 7). The steep hill rising above the road is called locally Glass Mountain, and the obsidian is known as "bottle rock."

The obsidian occurs not in a massive flow deposit but as nodules, rarely larger than a man's fist, imbedded in a soft white pumice deposit. The entire steep hillslope is mantled, in places so thickly that no vegetation can exist, with shiny black obsidian flake refuse. Visible on this hillside slope are at least 100,000 cubic feet of obsidian flakes. Mixed with the rough, unused flakes are numerous implement blanks rejected because they were too thick or because they broke during the preliminary shaping. Large numbers of round hammerstones of sandstone, rhyolite, quartzite, or tuff are found scattered throughout the flake mantle. These were used to break the obsidian nodules and strike off the flat flakes which could be fashioned into blades and points.

On the crest of the hill (figure 7) are a series of shallow pits about six feet in diameter. These were formerly larger and deeper and have now been nearly filled by the deep layer of workshop material which covers the ridge. It would appear that the Indians dug out the obsidian nodules from these pits. The digging tools could have been simply sharpened sticks, for the nodules occur here in a solidly packed loose aggregate like gravel in a stream bed.

After the preliminary percussion flaking had produced blade blanks, these roughly chipped pieces were transported to neighboring sites along the Napa River, where they were finished into thin spears, knives, or arrowpoints by the pressure-flaking technique.

Bartlett (1854, vol. 2, p. 49) may refer to this site when he describes an obsidian outcrop on the farm of Mr. Kelley in Napa Valley.

Locality 3: Big Borax Lake near Clear Lake, Lake County (sec. 8, T. 13 N., R. 7 W., M. D.).

This obsidian deposit was owned by the Elem, a tribelet of the Pomo group, in whose territory the quarry was located. The Wintun tribe of Long Valley and the Miwok of Coyote Valley gathered and used the obsidian freely, though they had to receive permission from the Elem owners. Such understandings have the status of international agreements on the use of natural resources. (Gifford, 1923, p. 80.)

The quarry lies east of the old road from Clear Lake to Sulphur Bank immediately southeast of Borax Lake (see fig. 6). The outcrop of black rhyolitic obsidian extends on a north-south front of nearly half a mile where it was exposed on the western slope of the obsidian flow. The massive outcrop is now buried under an eight-foot blanket of refuse flakes, quarry rejectage, and hammerstones. The outcrop is now exposed in a quarry pit at the north end about forty yards upslope from the road. C. A. Anderson (1936) maps the extent of the obsidian flow and discusses it at length (pp. 654-56), appending a chemical analysis of the obsidian in his Table I, no. 13. The fragments of obsidian attributed by Anderson to natural weathering are more likely to represent Indian quarry waste.

The amount of waste obsidian scattered over the quarry and workshop area is so great that a quantitative estimate would run into several thousand tons and hundreds of thousands of cubic feet. There can be no doubt that we have here an obsidian source of great aboriginal importance, and one which was worked intensively over a long period of time. It would be difficult to account for the existence of these

extensive obsidian quarrying operations on the grounds that the Pomo Indians alone used the volcanic glass for arrow and spear points or knives. The explanation lies in the known fact that the Lake County obsidian was traded very widely to the north, south, and especially east to the tribes of the Sacramento Valley. The Pomo obsidian quarrymen and distributors may be looked upon as monopolists, a position which they took pains to capitalize upon through trade in this commodity.

Locality 4: On ridge between Eel and Russian Rivers, Mendocino County.

Obsidian boulders occur in this region, and these were searched for by the Indians, who made spearpoints of them. (Gibbs, 1860, pp. 114, 116.)

Locality 5: Cole Creek, Lake County.

A surficial obsidian deposit on Cole Creek was the source of material which the Indians recognized as serving particularly well for knives and shaving razors. The obsidian from this locality was called *dupa xaga*, "to cut obsidian" (Loeb, 1926, p. 179).

Locality 6: Mount Konocti (Kanaktai), Lake County.

This imposing peak, of volcanic origin, bears numerous obsidian exposures which were exploited by the Pomo Indians. The faces of volcanic glass flows have weathered and exfoliated so that fragments of obsidian are scattered widely over the slopes of the mountain. These fragments are explained by the Indian myth of Obsidian Man, previously discussed in this paper (Barrett, 1933).

Locality 7: Glass Mountain, Modoc County.

Somewhere on this volcanic mountain (the exact spot is not recorded) was a large obsidian quarry from which the Atsugewi, Achomawi, Yana, and McCloud River Wintu secured implement material. (Voegelin, 1942, p. 191; Kniffen, 1928, p. 306.) The geology, with a map showing extent of the obsidian flow of Glass Mountain, is given by C. A. Anderson (1933).

Locality 8: Sugar Hill, Modoc County.

This is another large volcanic mountain with an excellent and aboriginally far-famed obsidian deposit. The Achomawi knew and used this deposit, as did the Pit River peoples and their neighbors to the north, the Northern Paiute. Between these two latter groups the Sugar Hill quarry was the source of contention since both claimed to own it. (de Angulo and Freeland, 1929, p. 315; Kniffen, 1928, p. 306.)

Locality 9: Williams Valley, Mendocino County.

It is stated by Kroeber (1932, p. 370) that the Yuki Indians of Williams Valley had in their territory a pit or quarry for *kichil* (flint or obsidian) from which arrow-points were made.

Locality 10: South end of Cowhead Lake, Modoc County.

An obsidian exposure in this locality was visited by the Paiute of Surprise Valley when arrowhead material was needed. (Kelly, 1932, p. 14.)

Locality 11: Glass Mountain between Bishop and Mono Lake, Mono County.

The Piaute of Owens Valley got obsidian from this source (Steward, 1933, p. 262).

Locality 12: Fish Springs, Inyo County.

Volcanic rocks (probably obsidian) from this locality were used by Owens Valley Paiute (Steward, 1933, p. 262).

Locality 13: North of Big Pine, near Bishop, Inyo County.

This obsidian quarry was worked by Owens Valley Paiute (Steward, 1933, p. 262).

Locality 14: Bertrand Ranch, 60 miles northwest of Benton, Mono County.

The Owens Valley Paiute considered the obsidian from this source to be "poisonous." A number of other California Indian tribes share this belief in the reputed toxic properties of obsidian (Steward, 1933, p. 262).

Locality 15: Obsidian Butte on southeast shore of Salton Sea, Imperial County.

There are numerous evidences of aboriginal exploitation around this butte in the form of discarded or waste flake material. The obsidian from this locality contains small gaseous blow holes which are lined with a calcium deposit. This characteristic obsidian has been found at ancient Indian camp sites from San Felipe on the Gulf of California northward to Palm Springs and eastward to the Colorado River (Treganza, 1942, p. 155, fn. 13).

Locality 16: Head of Napa Valley, Napa County (Ball, 1941, p. 58).

Locality 17: Upper Sonoma Valley, Sonoma County (Ball, 1941, p. 58).

Locality 18: Wheatland, Yuba County (Ball, 1941, p. 58).

Locality 19: Cortina, Colusa County (Ball, 1941, p. 58).

Locality 20: Mt. Kilili, near Tuolumne, Tuolumne County (Barrett and Gifford, 1933, p. 218).

Locality 21: Near Fillmore, Ventura County (Walker, 1936, p. 15).

Locality 22: Coso Hot Springs at south end of Coso Mountains, Inyo County, approximately 20 miles southeast of Owens Lake and 140 miles northeast of Los Angeles.

The quarry lies four miles west of the main group of springs and near the crater of an extinct volcano. An abundance of chipped rejectage material lies along the talus of the outcrop. Obsidian hammerstones averaging about a pound in weight and subtriangular in shape were used to quarry the material and to break it into flat, portable pieces (Farmer, 1937).

Locality 23: Black Rock, on the Dos Rios-Laytonville road, about 4 miles north of the first ridge between these towns, going from Dos Rios.

Both the Kato and the Yuki tribe claimed this useful and valuable obsidian deposit. This difference led to strife, and the resulting war is graphically told in *A Kato War* (Kroeber, 1928, p. 396).

Locality 24: Deer Creek, Tehama County.

The Yahi Indians collected obsidian in boulder form and traded it to neighboring tribes (Pope, 1918, p. 116).

Steatite

(Map 2)

The general term steatite as used here includes different but closely allied minerals such as soapstone, magnesian mica, and talc.

This soft, easily worked stone with heat-tolerant qualities was a popular material among all the California Indian tribes. Because it did not crack when heated, it was the ideal substance from which to make smoking pipes (fig. 10, *a-c*). The tubular steatite pipe occurs archaeologically throughout the whole State. The Klamath River tribes made flat drip-pans to collect grease over the fire, and similar pans (fig. 10), upon which wild seed cakes were roasted, were a product of the Chumash tribe of the Santa Barbara Channel region. The Indian technique of ''stone boiling'' (by repeatedly dropping hot stones in a liquid) could be practiced with basket containers provided the stones were kept in motion and not allowed to rest against the basket itself. The Maidu Indians of Auburn, Placer County, heated fist-sized steatite lumps and dropped them in baskets containing acorn mush to boil it. Several southern tribes made finely shaped steatite bowls in which to cook wild seed mush, but it is not known whether these were set directly over the fire or used with stone-boiling technique. Such a steatite bowl which was easily made and would last indefinitely provided it was not dropped and broken, was superior to a perishable and fragile basket and equal to a pottery bowl in every respect except weight. The reason the Santa Barbara Chumash did not make pottery vessels was probably because their baskets and soapstone bowls were completely satisfactory. Asphalt-coated basketry bottles which were water-tight, and stone pots which could be set directly over a fire were equal to any pottery. Tall cylindrical jars of steatite were made by the ancient peoples of the Stockton-Lodi region (fig. 10*f*) but their use is unknown. Steatite was in general use for beads and pendants which, even by modern standards, were objects of beauty. When worn next to the skin the dark steatite absorbed oil and developed a deep, shiny luster. Steatite disk beads were often strung alternately with contrasting white mates of magnesite.

Although soapstone was in general use in aboriginal California, and was an important material singularly adapted to specialized use, it was of

primary importance in only one area, the Santa Barbara Channel region. The major source from which most of the steatite used in the whole local area was quarried was on Santa Catalina Island. However, San Clemente Island is said by Alexander S. Taylor to have been a source of soapstone used locally; H. C. Ford reports that steatite was mined by the mainland Indians in the San Rafael mountains (Ford, 1887, p. 15); and H. C. Yarrow states that soapstone quarries were located on Santa Rosa Island (Yarrow, 1879, p. 44). Mainland sources were known to have been utilized, though probably to a lesser extent than the Santa Catalina Island deposit.

Locality 1: Santa Catalina Island.

The main quarries were ten miles northeast of Avalon at Pots Valley and Little Springs. A third quarry lies about 50 yards to the northwest between Pots Valley and the second ravine. A fourth quarry is about 400 yards east of Pots Valley boat landing close to the steep cliff. Some of the quarry pits, where the Indian followed a good "vein" are up to fifteen feet in diameter and five feet deep.

This quarry group was discovered by Paul Schumacher in 1876, and published accounts appeared a few years later (Schumacher, 1878, 1879, 1880). It was not a chance discovery, since the early Spanish explorers had spoken of the island as a source of steatite bowls seen by them on the mainland. W. H. Holmes visited the Catalina quarries in 1898 and wrote an excellent account of them as they then appeared (Holmes, 1902, pp. 183-184).

Schumacher found at the main quarry in Pots Valley many tools (fig. 3) and unfinished artifacts. Chisels of hard slate quarried nearby were used to work the soft steatite stratum. The pot form was worked out of the bed rock until a globular mass attached by a small pedestal remained. This mass was broken off (fig. 8) and the interior was gouged out with quartzite scrapers (fig. 3*f*); it was then smoothed by rubbing the surface with flat sandstone "files," and finally polished with some softer material. Amsden (1930) mentions granite quarry picks, though it is difficult to visualize this material as very suitable. A grooved stone axe collected by Schumacher at the Pots Valley quarry suggests that a hafted tool may have been used occasionally to extract the steatite chunks from the matrix.

The softer more micaceous Catalina steatite was used for pots and bowls (fig. 10*e*), while the closer-grained darker variety was made into arrowshaft straighteners (fig. 10*d*), weights for digging sticks, pipes (fig. 10*c*), and objects of adornment (beads, pendants).

According to Kroeber (1925, p. 629) the native Catalina steatite industry was interrupted by the coming of the Spaniards, since they not only gathered the Indians into the Missions, but also introduced metal containers which were superior to the steatite bowls of the Indians. In native times, completed steatite bowls were carried from Catalina to the mainland towns of Redondo and San Pedro, and from there were traded inland and along the coast. Carter's excavations at Point Sal, some 140 miles north of Redondo produced very little steatite, presumably because of the distance from the southern source of supply (Carter, 1941, p. 221). It is stated that Catalina steatite was found in native use as far east as the Grand Canyon of the Colorado (Randolph, 1935, p. 7).

Locality 2: Klamath River at a place called *Sihtirikusam* by the Karok Indians, Humboldt County.

The steatite quarried here by the Karok is considered by them to be soft and easily worked, and to be "very good looking" when made up into finished artifacts. From this material was made smoking pipe bowls, flat paving stones used on the "patio" in front of the sweathouse, and flat trays used to catch grease drippings (Harrington, 1932, p. 154).

Locality 3: On left bank of Klamath River just above the mouth of the Salmon River at a place called *Katimin* by the Karok Indians, Humboldt County.

At Katimin, a spot believed to be the center of the Karok world, is a large rock called "pipe bowl rock," considered sacred and for Indian use only. As the Indian name implies, the rock is used for making pipe bowls. The pipe bowl is pecked out in a circle leaving a central core supported by a pedestal which is broken off last. The bowl is then drilled and smoothed. The rock from Katimin is called by the Indians *asuxusas*, "soft rock" (Harrington, 1932, p. 151).

Just below Katimin is another deposit of quite soft and translucent soapstone, which shows greenish streaks when held up to a strong light. It is said by the Indians

to be not much good for making pipes because it cracks when it gets hot (Harrington, 1932, p. 153).

Locality 4: Near Tuolumne in the canyon of the north fork of the Tuolumne River, about one mile east of the town, Tuolumne County.

A stratum of steatite occurs at the same level in both the north and south walls of the canyon, and is exposed by the old Duckwall road. This deposit was known to the Sierra Miwok tribe, who call the locality *Lotowayaka.* Bowls and arrow straighteners were made of this material, and powdered steatite was used on babies to relieve chafing under the arms and between the legs. This is an ancient use of talcum powder, a custom also practiced by the Pomo tribe of Lake County, the Washo of the Lake Tahoe area, and the Yokuts of the Tulare Lake region (Barrett and Gifford, 1933, p. 211).

Locality 5: Four miles northeast of Lindsay, Tulare County.

A large open cut where talc has been quarried commercially in modern times marks the deposits. The aboriginal workings have not been disturbed, since they lie above the modern cut. E. F. Walker's report on this quarry states that the outcrop is in the form of laminated sheets of varying thickness tilted in a nearly vertical plane so that the quarrying operation consisted simply of breaking down the sheets with stone picks and mauls. A few shallow pits on the ridge indicate that some effort was made by the Indians to secure subsurface, unweathered chunks of steatite here. Scattered about the quarry site were examples of stone picks, mauls, and scrapers made of stone foreign to the immediate locality, a very hard bluish-black metamorphic rock with sharp-chipped pointed or cutting edges. Much of the loose steatite on the ridge exhibited marks of stone implements, and numerous rejects of bowls and cooking slabs in roughed-out form were found on the quarry dump (Walker, 1935; Wedel, 1941, p. 53).

Locality 6: Near mouth of Carrizo Gorge in the northeast portion of Jacumba Valley, San Diego County.

The deposit is an open exposure on a side hill. Apparently, as is the general rule with California Indian stone quarries, artifacts were roughed out on the spot in order to make certain the stone did not contain flaws and to save carrying extra weight. Five well fashioned steatite "plates" were found cached at the foot of the deposit in 1940. Arrowshaft straighteners found locally appear to be of stone from this quarry (Treganza, 1942, p. 157). The Kamia tribe of the Imperial Valley are said to have obtained soapstone for implements in the Jacumba Valley, though whether from this deposit or not is not stated (Gifford, 1931, p. 29). The Luiseño Indians used powdered soapstone for white color in their religious sand-paintings (Kroeber, 1925, p. 664). The Diegueño Indians used powdered soapstone for white body paint (Waterman, 1910, pp. 298, 309).

Locality 7: West side of Williams Valley, in ravines opening into the valley, Mendocino County.

Here the steatite occurs abundantly as pebble float material. Ancient village sites in Williams Valley area produce many worked pieces of this steatite (Treganza, Smith, and Weymouth unpublished manuscript).

Locality 8: Santa Ynez Mountains, and near Arroyo Grande. Exact localities unknown (Kroeber, 1925, p. 567).

Locality 9: Santiago Canyon, near Mount Pinos in the San Emigdio Range about 25 miles south of Buena Vista Lake (Wedel, 1941, p. 53).

Locality 10: Table Mountain, near Belleview, Madera County.

The Chukchansi subtribe of the Yokuts got steatite at this locality. After a fresh piece was quarried it was shaped and "cooked" overnight in a fire to harden it (Gifford, 1932, p. 25).

Locality 11: Fish Creek Mountain, Fresno County.

Quarry situated along a small creek between the stage road and San Joaquin River, to the right of the road to Auberry (Gifford, 1932, p. 25).

Locality 12: Northeast of Cloverdale, between Cloverdale and Lake County line on old Indian trail.

Steatite was used by the Pomo for pipe bowls, for "chalk" to mark stones, and in powdered form as talcum for babies (Gifford and Kroeber, 1937, p. 179, notes 252, 253).

Locality 13: Near Burnt Ranch on North Fork of Trinity River just above mouth of New River, Trinity County.

The Chimariko Indians gathered steatite from a ledge here and made eating vessels and water containers of it (Driver, 1939, p. 388).

Pigments

(Map 3)

Paint pigments in the colors most commonly found in nature (red, black, green, white, yellow) were used extensively by all California Indians. Red was most widely used, partly because it was easily obtainable. Colored pigments were used for body painting on festive occasions (red, white), or during the mourning period after a death (black); to make colored designs on pottery (red, black, yellow); for making pictographic designs on rock walls, the so-called ''Indian writing'' (red, white, black, yellow); for decorating utilitarian and ceremonial objects of wood with pleasing designs (all colors); for drawing intricate designs of symbolic significance with colored sands (all colors); as a prophylactic against skin eruptions on small children (red); and to protect the complexion from the sun's rays (red).

Hematite

Locality 1: East of the Sierra Nevada in territory of the Eastern Mono tribe.

The red pigment was called by the Sierra Miwok *a'wa* and *moke.* They secured it by trade from the Eastern Mono who held the monopoly on the deposit in their territory (Barrett and Gifford, 1933, p. 224).

Locality 2: Mountain between Lake Eleanor and Cherry River called *Voloamu* by the Sierra Miwok Indians.

The hematite lumps were ground to powder on a flat stone, and the powder mixed with water served as red paint with which the native dancers decorated their bodies (Barrett and Gifford, 1933, p. 224).

Locality 3: North end of Black Butte, Cocopa Mountains, on the United States-Mexico boundary, Imperial County.

Called *Akwurawawa,* "red place," by the Cocopa Indians. This hematite was a dull reddish color, and to make the color brighter the Cocopa dug a hole and built a fire in it. The oxidizing effect of the flames turned the material brilliant red. This was then pried out in chunks and put in water to leach out the salt content and soften the lumps into a pasty mass. The pigment was used to paint the Indians' bodies for festive occasions, and was applied to young children (two years old) as a prophylactic against skin eruptions (Gifford, 1933, p. 278).

Locality 4: Seven miles east of Petaluma, Sonoma County.

The hematite outcrop lies about 150 yards west of the highway between Petaluma and Santa Rosa. Old settlers state that this locality was the resort of Indians bent on securing red paint material, and it is said that old workings in the form of shallow pits, now nearly obscured by debris filling, are present. (M. Vonsen, personal communication.)

Locality 5: Northeastern San Diego County.

The Luiseño tribe collected hematite at this locality to use as face paint for girls at the adolescent ceremony. The paint was called *Paismul,* as was iron oxide collected at certain springs (Strong, 1929, p. 295).

Locality 6: Mineral springs in San Diego County.

The Diegueño Indians used the red oxide of iron powder collected from mineral springs to make designs in their religious sand-paintings (Waterman, 1910, p. 301). The brown iron pigment may be due either to *Crenothrix,* an iron-secreting vegetable organism, or the presence of carbon dioxide in the spring waters which holds the iron in solution until the gas escapes.

Locality 7: Jacumba Valley, San Diego County.

The Kamia Indians of Imperial Valley made the journey westward to Jacumba Valley to secure hematite for red paint (Gifford, 1931, pp. 35, 42).

Locality 8: Near mouth of Carrizo Canyon on east side of Jacumba Valley, San Diego County.

Along the volcanic contact lines there were deposits of hematite which the Indians dug out. It was used for body painting and for decorating pottery (Rogers, 1936, p. 12; A. E. Treganza, personal observation).

Locality 9: Junction of Redwood Road and Mountain Boulevard, Oakland Hills, Alameda County.

An outcrop of hematite shows signs of having been worked by Indians, and mortar holes in the rocks nearby with pigment adhering to the walls indicate that the hematite chunks were crushed into powder here on the spot (W. Wallace, personal observation).

Locality 10: Big Valley to the north of Mount Bidwell, Modoc County.

The Paiute of Surprise Valley state that they secured hematite at this locality. They also knew of a deposit behind the Harrison Brown ranch at Beatty, Oregon (Kelly, 1932, p. 116).

Locality 11: Colorado River, San Bernardino County.

This was territory claimed by the Mojave Indians, but Southern Diegueño from across the desert occasionally made the trip to a hematite deposit near the river to collect pigment. Such expeditions, made by several men, were hazardous on account of the difficult nature of the country and the possibility of encountering unfriendly strangers, and serve to illustrate the importance of this red paint material to the Indians. (Spier, 1923, p. 341.)

Locality 12: Vicinity of Santa Barbara, Santa Barbara County.

There are vague reports of hematite deposits in the mountains east of Santa Barbara. The coastal Chumash tribe who occupied the Channel area made very extensive use of hematite pigment for painting their bodies and utensils. Hugo Reid's early account of the Indians of Los Angeles County states that the old Gabrieleño women used red ocher (i.e. rouge) to protect their complexions from the sun's rays. There are a number of caves in the mountains which contain highly complex and colored pictographs made by the Indians. Graves from the coastal shellmounds often yield large moulded "loaves" of hematite (Harrington, 1928, p. 102; Abbott, 1879, p. 261).

Manganese

Manganese was used by the Indians for black paint. When Vizcaino touched at the Santa Barbara area in 1602 he found the Indians painted. He says:

"The black paint, or rather blue paint, appeared to be silvered, and . . . they displayed some stones of metal of London blue, from which they made it." (Wagner, 1929, p. 233.)

This may have been either galena from the Santa Catalina Island deposit which Martinez saw the Indians using in 1792, or the mixture of manganese and specular hematite found in the Indian graves near Santa Barbara (Abbott, 1879, p. 262).

Locality 1: Vicinity of Mono Lake, Mono County (Steward, 1933, p. 277).

Locality 2: North end of Black Butte, Cocopa Mountains on United States-Mexico line, Imperial County.

The quarry was called by the Cocopa Indians *Kwinyilwawa*, "black place." The manganese occurred as a "salty," hard rock which was broken up by burning; afterwards it was pulverized, and was then ready to use as paint (Gifford, 1933, p. 278).

Locality 3: Jacumba Valley, San Diego County.

This deposit of psilomelane was worked by the Kamia of Imperial Valley (Gifford, 1931, p. 35).

Limonite

Locality 1: Vicinity of Santa Barbara, Santa Barbara County.

This limonite occurs commonly in Indian graves (Harrington, 1928, p. 102).

Locality 2: Andrade, just south of Mexican boundary.

Used as a pigment for painting pottery (Rogers, 1936, p. 32).

Locality 3: Near the Pot Holes on the Colorado River, Imperial County.

Used for painting designs on pottery (Rogers, 1936, p. 32).

Cinnabar

The California Indians mined cinnabar, which was used by them for body paint, in at least two places within the State. These were the famous New Almaden mine near San Jose, and Last Chance Peak, Death Valley. Alexander S. Taylor mentioned in a newspaper account (1864) that the New Idria locality was known to the Indians, but there is no evidence other than this offhand reference. Both authors have heard second-hand reports that the Pomo Indians of Lake County mined cinnabar for face paint, but here also there is no direct evidence.

The New Almaden locality was very well known to the natives of northern California and its fame had spread as far north as the Columbia River.

Locality 1: New Almaden Mine, Santa Clara County.

The surface outcrop of this deposit was no doubt discovered by some fortunate Indian many centuries ago. The earliest historical records of the locality mention a tunnel driven a hundred feet by the primitive mining methods of the Indians.

In the evidence of the famous Castillero Suit concerning ownership of the New Almaden mine, we read that Don Andres Castillero states he sent the first specimens to Mexico for determination, and asked for means to work "a mine which he has discovered in the Mission (district) of Santa Clara, known by the old Indians, who used to obtain therefrom vermillion to paint their bodies with." It is significant that Castillero states he discovered a "mine," for our other evidence indicates that is precisely what he did, the mine being the old Indian tunnel which originally started at the surface outcrop.

James G. Swan writing in 1857 about the Pacific Northwest, has an interesting statement to make about the Columbia River peoples (Walla Walla tribe) who came to California to trade for horses and secure New Almaden cinnabar. His statement, together with other inferences we may draw concerning the Walla Walla expeditions to California (Heizer, 1942), leads to the conclusion that the New Almaden locality was probably known to the Columbia tribes as early as 1800. Swan (1857, pp. 313-14) states:

> "That the northern tribes, or those of Oregon and Washington, have been accustomed to long journeys south, is a fact which is easily shown. When Fremont first commenced hostilities in California, a large body of Walla Walla Indians from the Columbia were creating disturbances in the region of Sacramento. These Indians formerly made regular excursions to the south every year, on horseback, for the purpose of trade and plunder.
>
> "The wife of Mr. Ducheney, the agent of Chinook for the Hudson Bay Company, who is a very intelligent woman, informed me that, her father was (a) Frenchman, and her mother a Walla Walla Indian, and that, when she was quite a child, she recollected going with her mother and a party of her tribe to the south for a number of months; that they were three months going and three months returning; that they took horses with them, and Indian trinkets, which they exchanged for vermillion and Mexican blankets: and that on their return her mother died and was buried where the city of Sacramento now stands . . . She was too young to remember how far into Mexico they went, but I judged that the vermillion she mentioned was obtained from the mountains of Almaden near San Jose, California."

J. W. Revere, who participated actively in the Bear Flag Revolt, states that the New Almaden mine was worked by the Indians for red paint (Revere, 1848, p. 55). Alexander S. Taylor, in an article on the Indians of Santa Cruz County states,

> "The Indians of Santa Cruz and Santa Clara (Mission) seem to have always have been in fights about the possession of the cinnabar mine, now the immensely rich New Almaden. The Indians away from the Tulares and Sacramento, were also accustomed to come often to get their share of the 'red paint,' and great battles were often fought in these 'vermillion expeditions.' One of them occurred even as late as 1841 or 42, when several of the intruders were killed by Santa Clara Indians." (Taylor, 1860; 1864.)

We have two excellent accounts of the Indian workings. The first, by J. K. Lord, is as follows:

> "Long ere gold was discovered in California, the Padres and early settlers knew of a cavern in the hillside, about a mile and a half from the present village. (It) proved to be in length one hundred feet running into the mountain horizontally. No one ever thought it was an artificial excavation of great antiquity . . (After discovery of cinnabar) the original opening (was) widened (in) clearing away the rubble and dirt at the end of the cave. Several skeletons were discovered, together with crude mining tools and other curious relics, clearly proving it an old excavation made by the natives for the purpose of securing vermillion, so much used by all savages to paint themselves. The position of the skeletons in the rubbish covering them left no doubt that having followed the vein of cinnabar without exercising due precaution to prop the loose ground overhead they had been literally buried alive in a grave of their own making" (Lord 1866, vol. 1, pp. 209-210).

An earlier account of the New Almaden mine and workings published in California reads,

> "We are still three hundred and thirty-three feet below the summit, where in 1845 a shaft was sunk, and mining first commenced. This point had been the resort of the aborigines not only of this State, but from as far as the Columbia River, to attain the paint (vermillion) found in the cinnabar, and which they used in the decoration of their persons. How long this had been known to them cannot be ascertained; probably a long time, as they had worked into the mountain some fifty or sixty feet, with what implements can only be conjectured. A quantity of round stones, evidently from the brook, was found in a passage, with a number of skeletons; the destruction of life having been caused, undoubtedly, by the sudden caving of the earth burying the unskilled savages in the midst of their labors." (Downer, 1854, p. 221.)

It seems probable that the large amount (five or six pounds) of cinnabar which was recovered from Indian graves near Knightsen, Contra Costa County, came originally from New Almaden. The burials probably date from about 1800. (Lillard, Heizer, and Fenenga, 1939, p. 72.)

Mr. E. Bulmore whose father was accountant and hacienda foreman of New Almaden from 1892-1900, has made inquiries into the history of New Almaden, and informs the authors in a letter that Captain Castillero and Padre Real of Mission Santa Clara learned of the "vermillion cave" from the Indians. He further states that some of the cinnabar pigment was used to paint the Mission in 1826, and that not until 1845 were experiments made which proved the red pigment to be cinnabar.

Mr. Bulmore also outlines an "Indian legend" to the effect that the "Great Spirit" appeared before Chief Umunhun and told him to direct his warriors to wash themselves to cure themselves of the sickness caused by excessive use of the cinnabar pigment. The implication here is that the Indians became salivated by the mercury. Since the "Great Spirit" of this story is identified as a saint of the Catholic church (Santa Teresa), the tale is probably of post-Spanish origin, and ascribable to the authorship of Indian laborers who worked for the Spanish in the first primitive retort in which gun barrels were used as condensing tubes. One often hears the question asked, "Did the Indians suffer injurious effects from the use of cinnabar face paint?" The use of cinnabar will not cause personal injury, and if the Indians ever did suffer ill effects, some special explanation is needed to account for them. Long ago this same question came up concerning ancient Egypt, and the statement made above is consonant with the accepted conclusion of careful studies made at that time.

Locality 2: Near Last Chance Mountain, Death Valley, Inyo County.

The Owens Valley Paiute secured cinnabar for body paint from this locality (Steward, 1933, p. 276).

Silica Minerals

(Map 4)

The silica minerals chert, jasper, flint, chalcedony, petrified wood, and quartz crystals are of common enough occurrence to have been accessible in some quantity to most, if not all, of the California Indian tribes. An inspection of the extensive archaeological collections of the University of California shows that the siliceous cryptocrystalline rocks were used in all parts of the State in aboriginal times for chipped arrow and spear points and knives. The widespread and abundant use of these rocks for chipped implements implies many more sources than have been listed here. These materials have the advantage over glassy obsidian in strength and toughness, but are harder in general to flake into small, delicate, thin, projectile points. The Pomo Indians of Ukiah Valley used the local tough green radiolarian chert for drills, but generally selected obsidian for making arrow points (Stewart, 1943, pp. 44, 52). The glassy obsidian was too brittle to serve as a drill, for even slight pressure would cause it to snap off; but the tough, granular chert would stand up well. Examination of the stone drills in the University of California Museum of Anthropology abundantly bears out the observation that chert and flint were the favorite drill materials. The California Indians employed a number of methods of drilling. The usual small T-shaped flint drill held in the fingers was probably universally used for small objects. For long drill holes (cf. the steatite pipe shown in fig. 10*a*) a flint point was hafted to a wooden shaft and twirled between the palms; the object being drilled was held steady in a cleft stick vise or by a second person. Long tubular stone pipes or beads usually exhibit biconical drilling, the two drill holes meeting at about the middle of the tube. The Chumash of Santa Barbara drilled long, small holes (80 millimeters by 1 millimeter) in the soft laminated layer of a *Tivela* shell with a sea-lion's whisker drill and fine sand abrasive.

The Pomo Indians of Lake and Sonoma Counties were the manufacturers and purveyors of small disk shell beads for all the north-central California tribes and developed the making of flint drills into a specialized art followed by men who learned it from older relatives in the mother's family. These drill makers were called *dawi xaga duyi gauk*, "drill flint make person." (Loeb, 1926, p. 178; Gifford, 1926, p. 329.) Among the Wiyot of Humboldt Bay flint chippers were looked upon as specialized craftsmen (Powers, 1877, p. 104).

In the stratified Indian mounds of the lower Sacramento Valley a series of successive cultures and populations has been disclosed through excavation (Heizer and Fenenga, 1939). The stone tool assemblages of these different cultures are all somewhat different both as regards artifact forms and lithic materials employed (Lillard, Heizer, and Fenega, 1939, pp. 74-82). Different cultural heritages, each with its habitual (i.e. preferential) or traditional material forms; different sets of contacts with neighboring groups, from whom were derived, through trade, certain stone tool materials; and different estimations of the degree of utility of a material, all influence these variations in assemblages. Technological studies of stone tool types have only recently begun to seriously consider the cultural significance of the properties of the lithic materials (see for example Goodman, 1944; Ellis, 1940; Birch and Dennison, 1938).

Chert

Locality 1: Punto Año Nuevo, Santa Cruz County.

The main outcrop of brown banded gray, white, and brown chert is exposed along the beach line and extends seaward. Aboriginal workshop sites where this chert was chipped into artifacts or thin, portable implement blanks lie in the sand dunes behind the point. Several Indian shellmounds in the vicinity contain numerous pieces of this worked chert (A. E. Treganza, personal observation; T. J. Hoover, personal observation).

Locality 2: Round Valley, Mendocino County.

Three separate localities (Weymouth Ranch, Upper Town Creek, and north end of Round Valley) within this small valley are represented by the single map symbol. These are surface exposures of Franciscan chert which have been worked by the Indians through the simple means of knocking chunks off the main outcrop with a handy rock of sufficient size and weight. The area immediately contiguous to each of the outcrops is littered with spalls, rejected flakes, and imperfect blades. Numerous finished projectile points of this chert which have been excavated from the local Indian mounds also attest to its wide use (Treganza, Smith, and Weymouth, unpublished manuscript).

Locality 3: Coastal area immediately south of Mad River, Humboldt County.

There are large aboriginal flint workshops on the beach where the varicolored Franciscan cherts were chipped by the Indians. The chert quarries were probably in nearby Luffenholtz and Norton Creeks since the Wiyot Indians names for these streams and their canyons refer specifically to flint. Luffenholtz Creek is called *Tapelo*, "flint," and Norton Creek *Peltalinel*, "flint" (Lond, 1918, pp. 279, 288, 289).

Locality 4: Cloverdale, Sonoma County.

A hard greenstone (radiolarian chert) which had a granular texture and was extremely tough, was obtained near the old Indian village of *Amako*, across the Russian River from the Asti winery and near the present site of Cloverdale. This was used in the manufacture of heavy duty drills and arrowpoints (Stewart, 1943, p. 52).

Locality 5: Ukiah Valley, Mendocino County.

Near the old Pomo villages situated about five miles south of Ukiah was a large ledge of greenish-white chert which provided material for drill and other stone artifacts. For felling trees, Pomo Indians used a percussion-flaked axe held in the hand, and the tough Franciscan chert was selected as the material best suited for this implement (Stewart, 1943, pp. 44, 48, 53, site 15).

Locality 6: Longvale Creek, 10 miles south of Laytonville, Mendocino County.

An Indian trail ran from Darbie's store to Longvale Creek and a quarter of a mile from the creek on this trail was an outcrop of fine, hard, even-grained green chert from which the Indians obtained material for making arrowpoints and drills. The Indians state that tools made of this chert were more durable and practical than those made of glassy obsidian obtained by trade from their Lake County neighbors. (Stewart, 1943, p. 34, site 5.)

Locality 7: Potter Valley, Mendocino County.

In the valley was a good outcrop of chert from which the Pomo Indians made hard drills and arrowpoints. Obsidian, though it was abundant around Clear Lake, was considered a luxury. (Stewart, 1943, p. 40, site 10.) This particular green chert, so much used by the Pomo of Lake, Sonoma, and Mendocino Counties, was exported down Cache Creek and Napa Valley to the Indian villages of the Sacramento River and delta.

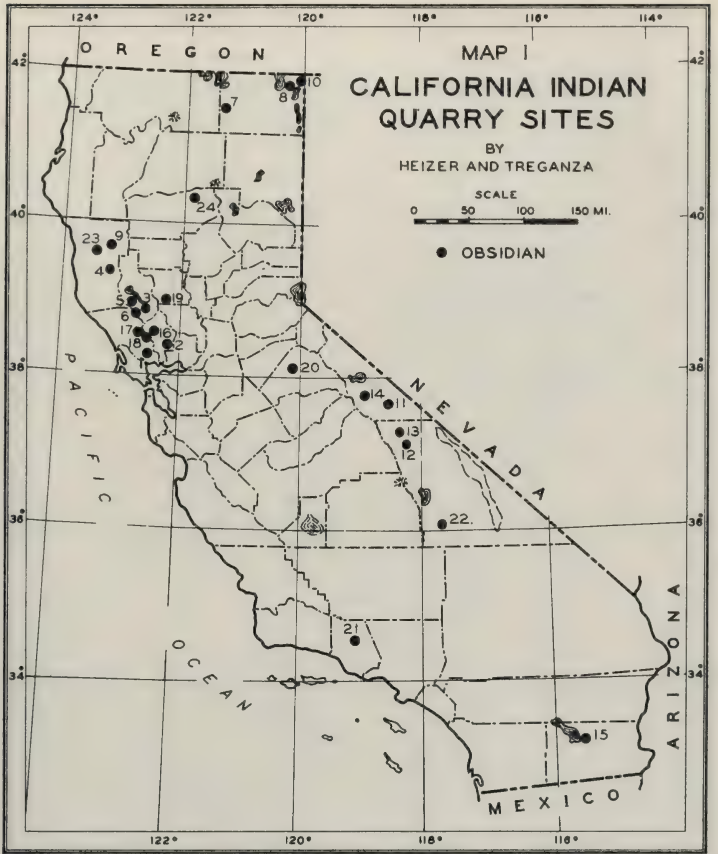
Jasper

Jasper seems to have been used sparingly by the Indians of California, and for the most part was gathered by chance discovery in gravel deposits rather than from massive outcrops.

The two chrysoprase localities (map 6) east of Visalia and north of Lindsay may prove upon further investigation to be spots where the Yokuts Indians quarried jasper.

Locality 1: Granite Mountains south of Death Valley, San Bernardino County.

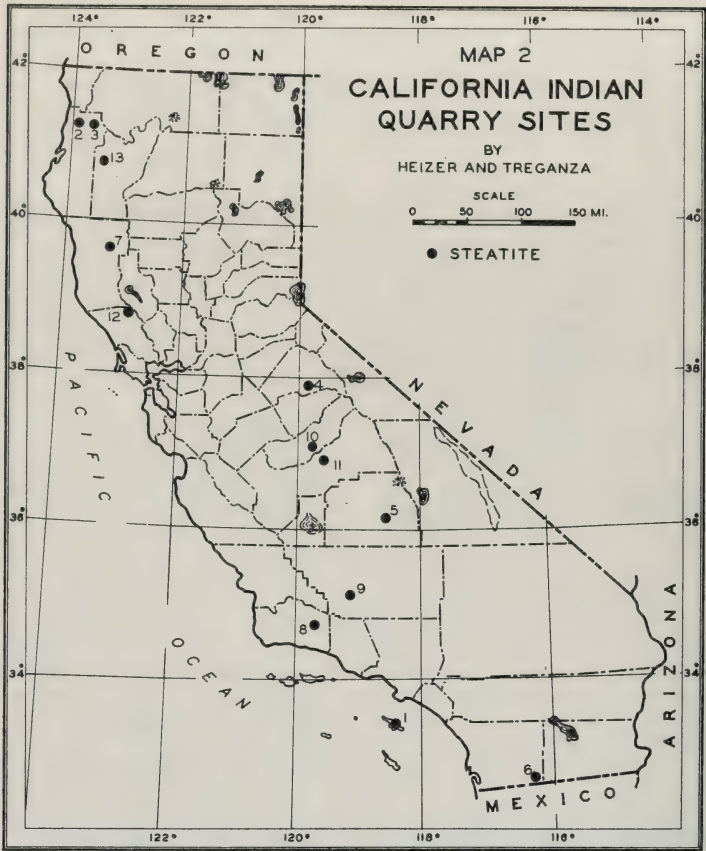
This deposit of birdseye jasper is now mined commercially by the Mexicans. That it was known to the aborigines is shown by its distribution in the form of artifacts (arrowpoints and scrapers) from Laguna Salada, Baja California, north to the Santa Rosa Mountains in Riverside County (A. E. Treganza, personal observation).



MAP 1

OBSIDIAN

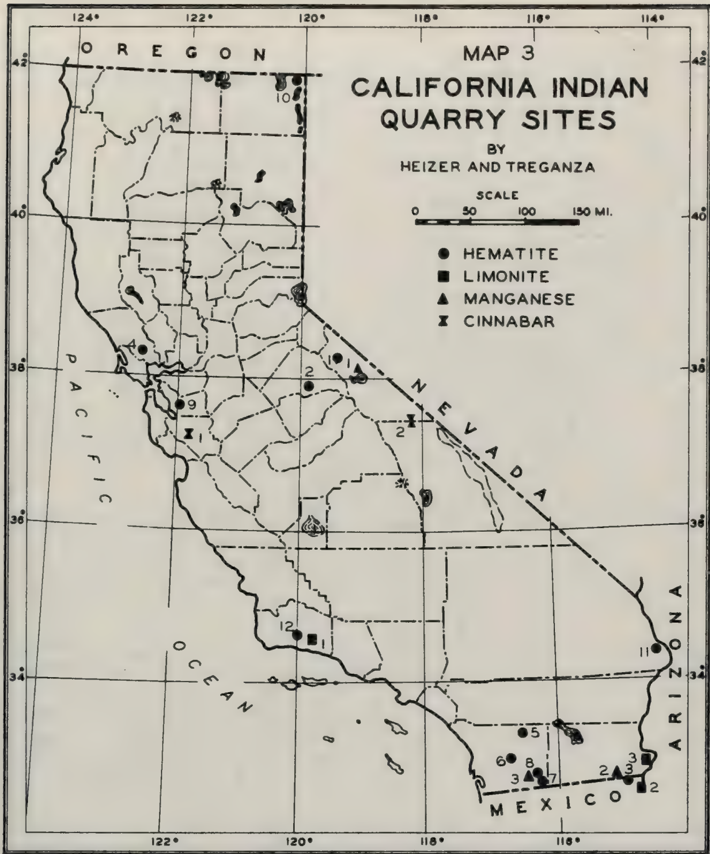
1. Near Anadel on the Southern Pacific Railroad about 7 miles southeast of Santa Rosa, Sonoma County.
2. East side of Napa River, near St. Helena, Napa County.
3. Big Borax Lake, Lake County.
4. Ridge between Eel and Russian Rivers, Mendocino County.
5. Cole Creek, Lake County.
6. Mount Konocti, Lake County.
7. Glass Mountain, Modoc County.
8. Sugar Hill, Modoc County.
9. Williams Valley, Mendocino County.
10. South end of Cowhead Lake, Modoc County.
11. Glass Mountain between Bishop and Mono Lake, Mono County.
12. Fish Springs, Inyo County.
13. North of Big Pine near Bishop, Inyo County.
14. Bertrand Ranch, 60 miles northwest of Benton, Mono County.
15. Obsidian Butte on southeast shore of Salton Sea, Imperial County.
16. Head of Napa Valley, Napa County.
17. Upper Sonoma Valley, Napa County.
18. Wheatland, Yuba County.
19. Cortina, Colusa County.
20. Mount Kilili near Tuolumne, Tuolumne County.
21. Near Fillmore, Ventura County.
22. Coso Hot Springs at south end of Coso Mountains, Inyo County.
23. Black Rock, Mendocino County.
24. Deer Creek, Tehama County.



MAP 2

STEATITE

1. Santa Catalina Island at Little Springs, and Pots Valley.
2. *Sihtirikusan*, Klamath River, Humboldt County.
3. *Katimin* on left bank of Klamath River just above mouth of Salmon River, Humboldt County.
4. About a mile from the town of Tuolumne on the old Duckwall road, Tuolumne County.
5. Four miles northeast of Lindsay, Tulare County.
6. Northeast side of Jacumba Valley, San Diego County.
7. West side of Williams Valley, Mendocino County.
8. Santa Ynez Mountains and near Arroyo Grande.
9. Santiago Canyon near Mount Pinos in the San Emigdio Range about 15 miles south of Buena Vista Lake, Kern County.
10. Table Mountain, near Belleview, Madera County.
11. Near Fish Creek Mountain, between stage road and the San Joaquin River, Fresno County.
12. Between Cloverdale and Lake County line, Sonoma County.
13. Burnt Ranch, Trinity County.



MAP 3

PIGMENTS

Hematite

1. East of Sierra Nevada in Mono Indian territory, Mono County.
2. *Vololamu,* a mountain between Lake Eleanor and Cherry River, Tuolumne County.
3. North end of Black Butte, Cocopa Mountains, Imperial County.
4. Seven miles north of Petaluma, Sonoma County.
5. Springs in northeast San Diego County.
6. Mineral springs in southern San Diego County.
7. Jacumba Valley, San Diego County.
8. Near mouth of Carrizo Canyon, northeast side of Jacumba Valley, San Diego County.
9. Oakland hills at junction of Redwood Road and Mountain Boulevard, Alameda County.
10. Big Valley, north of Mount Bidwell, Modoc County.
11. Colorado River, San Bernardino County.
12. Vicinity of Santa Barbara, Santa Barbara County.

Manganese

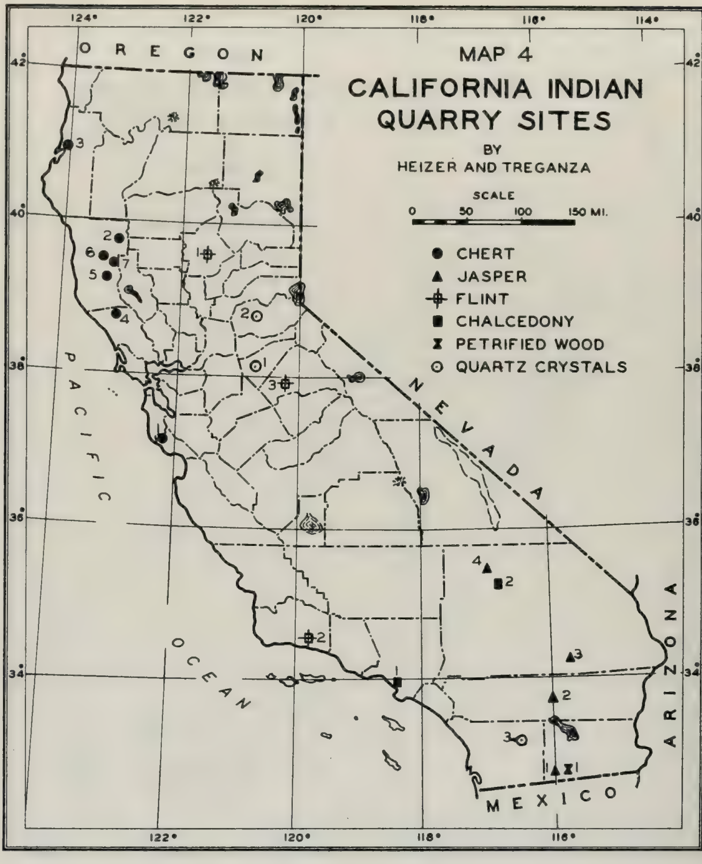
1. Mono Lake, Mono County.
2. North end of Black Butte, Cocopa Mountains, Imperial County.
3. Jacumba Valley, San Diego County.

Limonite

1. Vicinity of Santa Barbara, Santa Barbara County.
2. Andrade just south of Mexican boundary.
3. Vicinity of the Pot Holes near the Colorado River, Imperial County.

Cinnabar

1. New Almaden, Santa Clara County.
2. Last Chance Mountains, Inyo County.



MAP 4

SILICA MINERALS

Chert

1. Punta Año Nuevo, Santa Cruz County.
2. Round Valley, Mendocino County.
3. Just south of Mad River, Humboldt County.
4. Cloverdale, Sonoma County.
5. Ukiah Valley, Mendocino County.
6. Longvale Creek, Mendocino County.
7. Potter Valley, Mendocino County.

Jasper

1. Signal Mountain, Imperial County.
2. Forty miles south of Twenty-Nine Palms, Riverside County.
3. Forty miles north of Pinto Basin, San Bernardino County.
4. Granite Mountains, south of Death Valley, San Bernardino County.

Flint

1. Table Mountain near Oroville, Butte County.
2. Present settlement of Alcatraz, Santa Barbara County.
3. Near Tuolumne, Tuolumne County.

Chalcedony

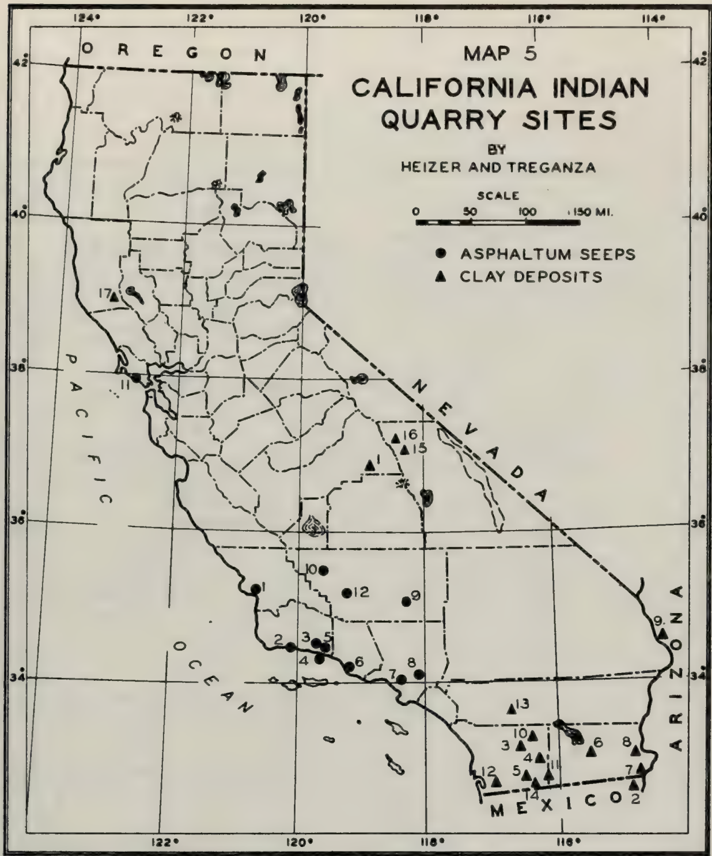
1. Redondo Beach, Los Angeles County.
2. About 100 miles northwest of Pinto Basin, San Bernardino County.

Petrified Wood

1. Pinto Mountain, Imperial County.

Quartz Crystals

1. Foothills of Calaveras County (Mokelumne Hill?)
2. Along American River, El Dorado County.
3. Near Pala, San Diego County.



MAP 5

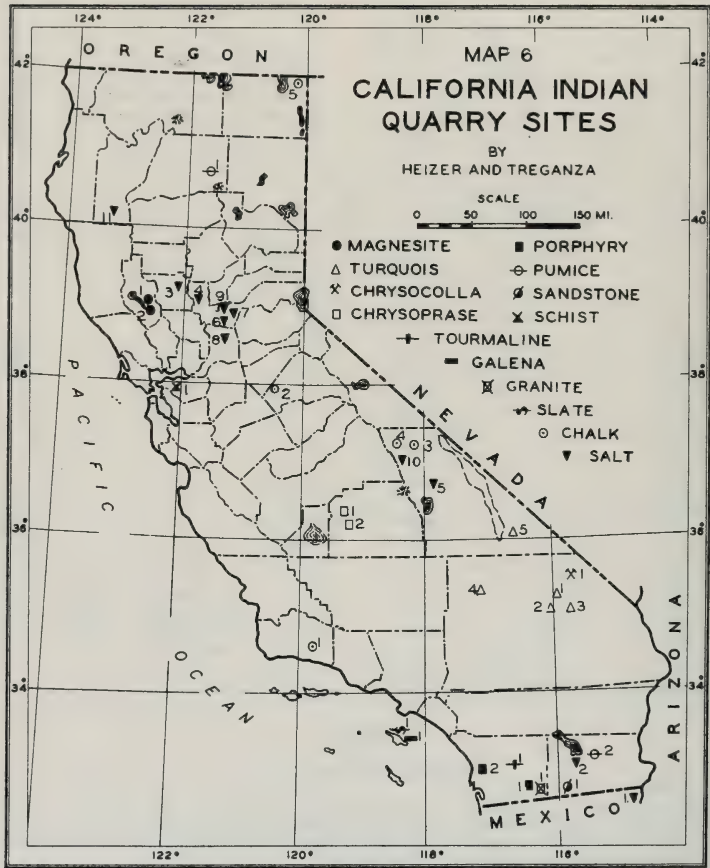
ASPHALTUM AND CLAY

Asphaltum Seeps

1. Mission San Luis Obispo, San Luis Obispo County.
2. Tajiguas Creek, marine seep, Santa Barbara County.
3. More's Landing at La Petera and Goleta Point, Santa Barbara County.
4. Santa Barbara, Santa Barbara County.
5. Carpenteria, Santa Barbara County.
6. Foot of Conejo grade, Ventura County.
7. La Brea pits, Los Angeles County.
8. Mission San Gabriel, Los Angeles County.
9. Southeastern Kern County.
10. McKittrick tar seep, southwest of Buttonwillow Slough, Kern County.
11. North of San Francisco Bay at Duxbury Point, Marin County.
12. West and south of Buena Vista Lake and in the vicinity of Maricopa and Hazelton, Kern County.

Clay Deposits

1. Dunlop, Fresno County.
2. Somerton Indian Reservation just below Mexican Line.
3. Slopes of Palomar Mountain, San Diego County.
4. Mason Valley, San Diego County.
5. Manzanita, San Diego County.
6. Lake-bed deposits in central Colorado Desert, Imperial County.
7. Flood-plain of the Colorado River.
8. Upper terraces of the Colorado River, Imperial County.
9. Base of Parker Mesa on Arizona side of Colorado River.
10. Borego Valley, San Diego County.
11. Dos Cabazes Springs, San Diego County.
12. Spring Valley, 10 miles east of San Diego, San Diego County.
13. White Water River at head of Cahuilla Valley, Riverside County.
14. Jewel Valley, San Diego County.
15. Fish Springs, Inyo County.
16. Baker Creek, Inyo County.
17. Potter Valley, Mendocino County.


MAP 6
CALIFORNIA INDIAN QUARRY SITES
BY
HEIZER AND TREGANZA
SCALE
0 50 100 150 MI.
MAGNESITE
TURQUOIS
CHRYSOCOLLA
CHRYSOPRASE
PORPHYRY
PUMICE
SANDSTONE
SCHIST
TOURMALINE
GALENA
GRANITE
SLATE
CHALK
SALT
OREGON
NEVADA
ARIZONA
MEXICO
PACIFIC
OCEAN

MAP 6

MISCELLANEOUS MATERIALS

Magnesite

1. Sulphur Bank, Clear Lake, Lake County.
2. White Buttes, near Cache Creek, Lake County.

Turquois

1. Turquoise Mountains, 10 miles northeast of Silver Lake, 3 miles east of the present Toltec turquois mines, San Bernardino County.
2. Turquoise Mountains, present site of Toltec mine, San Bernardino County.
3. Present site of Himalaya turquois mines, San Bernardino County.
4. Near Granite Wells, 22 miles east of Johannesburg, San Bernardino County.
5. Near Death Valley, Inyo County.

Chrysocolla

1. Turquoise Mountains, 10 miles northeast of Silver Lake, San Bernardino County.

Chrysoprase

1. Venice Hill, 8 miles east of Visalia.
2. Near Lindsay, Tulare County.

Tourmaline

1. Mesa Grande, San Diego County.

Galena

1. Santa Catalina Island.

Granite

1. Jacumba Valley, San Diego County.

Porphyry

1. Jacumba Valley, San Diego County.
2. San Dieguita Plateau, San Diego County.

Pumice

1. Hat Creek, Shasta County.
2. Pumice Butte on east side of Salton Sea, Imperial County.

Sandstone

1. Foothills of Sierra de Juarez, Imperial County.

Schist

1. Wildcat Canyon, Contra Costa County.

Slate

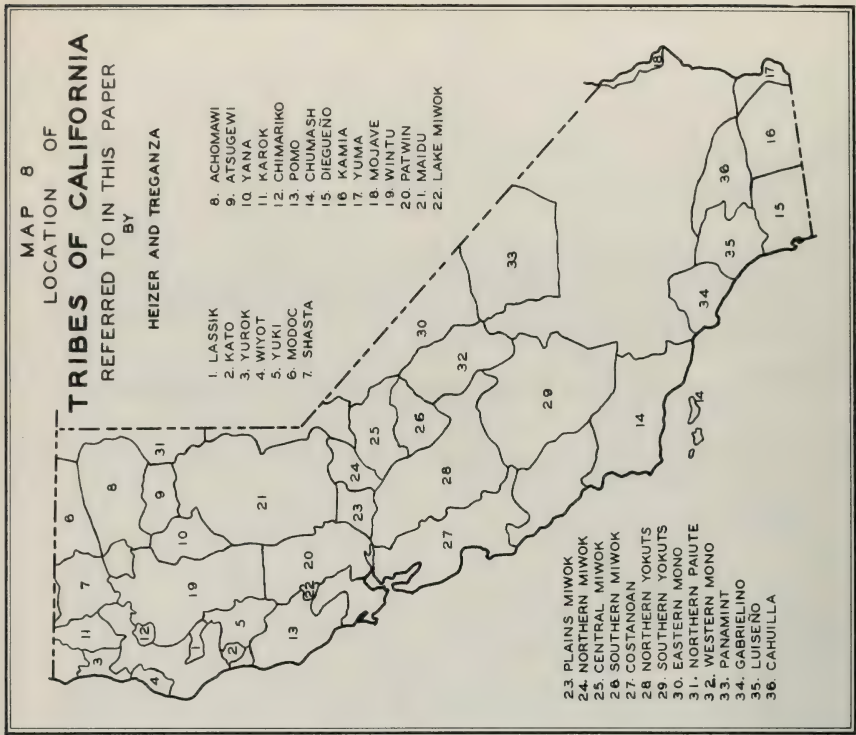
1. Santa Catalina Island near the pass at Pots Valley.

Chalk

1. Vicinity of Santa Barbara, Santa Barbara County.
2. Springfield, Tuolumne County.
3. East of Owens Valley, Inyo County.
4. Fish Springs Dam, eastern end of Poverty Hills, Inyo County.
5. Bidwell Mountain, Modoc County.

Salt

1. Between Sumerton and Yuma on Mexican side of line.
2. Southern edge of Salton Sink, Imperial County.
3. Big Stony Creek, Glenn County.
4. Near Marysville Buttes, Sutter County.
5. Saline Valley, Inyo County, east of Independence.
6. Salt springs near Rocklin, Placer County.
7. Salt marsh near Cool, Placer County.
8. Salt springs south of Folsom, Sacramento County.
9. Salt springs near Lincoln, Placer County.
10. Klondike Lake, Inyo County.
11. Forty miles east of Alderpoint, Trinity County.


MAP 8
LOCATION OF
TRIBES OF CALIFORNIA
REFERRED TO IN THIS PAPER
BY
HEIZER AND TREGANZA
1. LASSIK
2. KATO
3. YUROK
4. WIYOT
5. YUKI
6. MODOC
7. SHASTA
8. ACHOMAWI
9. ATSUGEWI
10. YANA
11. KAROK
12. CHIMARIKO
13. POMO
14. CHUMASH
15. DIEGUEÑO
16. KAMIA
17. YUMA
18. MOJAVE
19. WINTU
20. PATWIN
21. MAIDU
22. LAKE MIWOK
23. PLAINS MIWOK
24. NORTHERN MIWOK
25. CENTRAL MIWOK
26. SOUTHERN MIWOK
27. COSTANOAN
28. NORTHERN YOKUTS
29. SOUTHERN YOKUTS
30. EASTERN MONO
31. NORTHERN PAIUTE
32. WESTERN MONO
33. PANAMINT
34. GABRIELINO
35. LUISEÑO
36. CAHUILLA

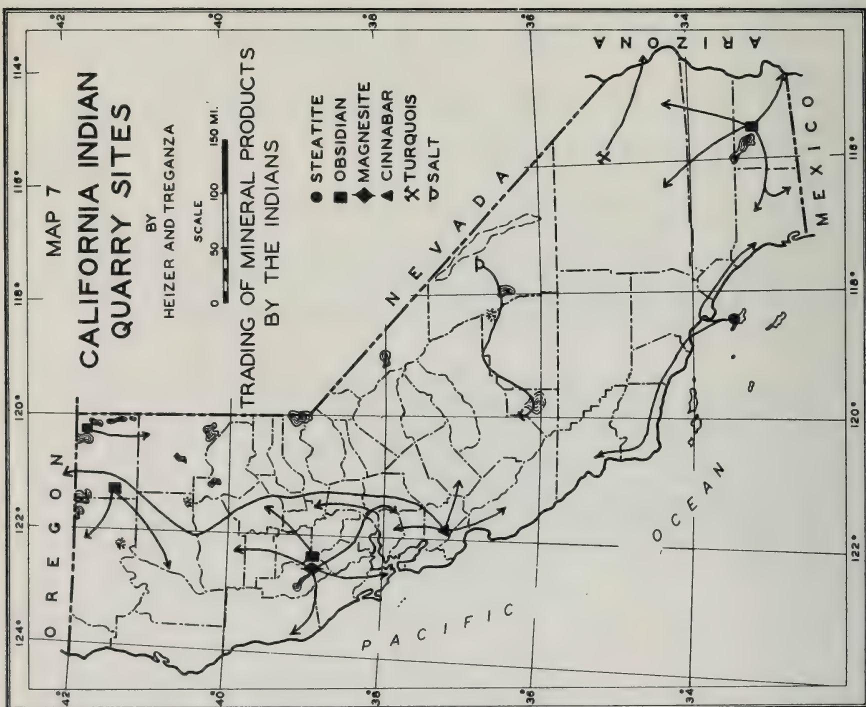

MAP 7
CALIFORNIA INDIAN
QUARRY SITES
BY
HEIZER AND TREGANZA
SCALE
0 50 100 150 MI.
TRADING OF MINERAL PRODUCTS
BY THE INDIANS
STEATITE
OBSIDIAN
MAGNESITE
CINNABAR
TURQUOIS
SALT
OREGON
NEVADA
ARIZONA
MEXICO
PACIFIC
OCEAN

Fig. 1. California Indians quarrying and chipping obsidian. (After life group in U. S. National Museum.)

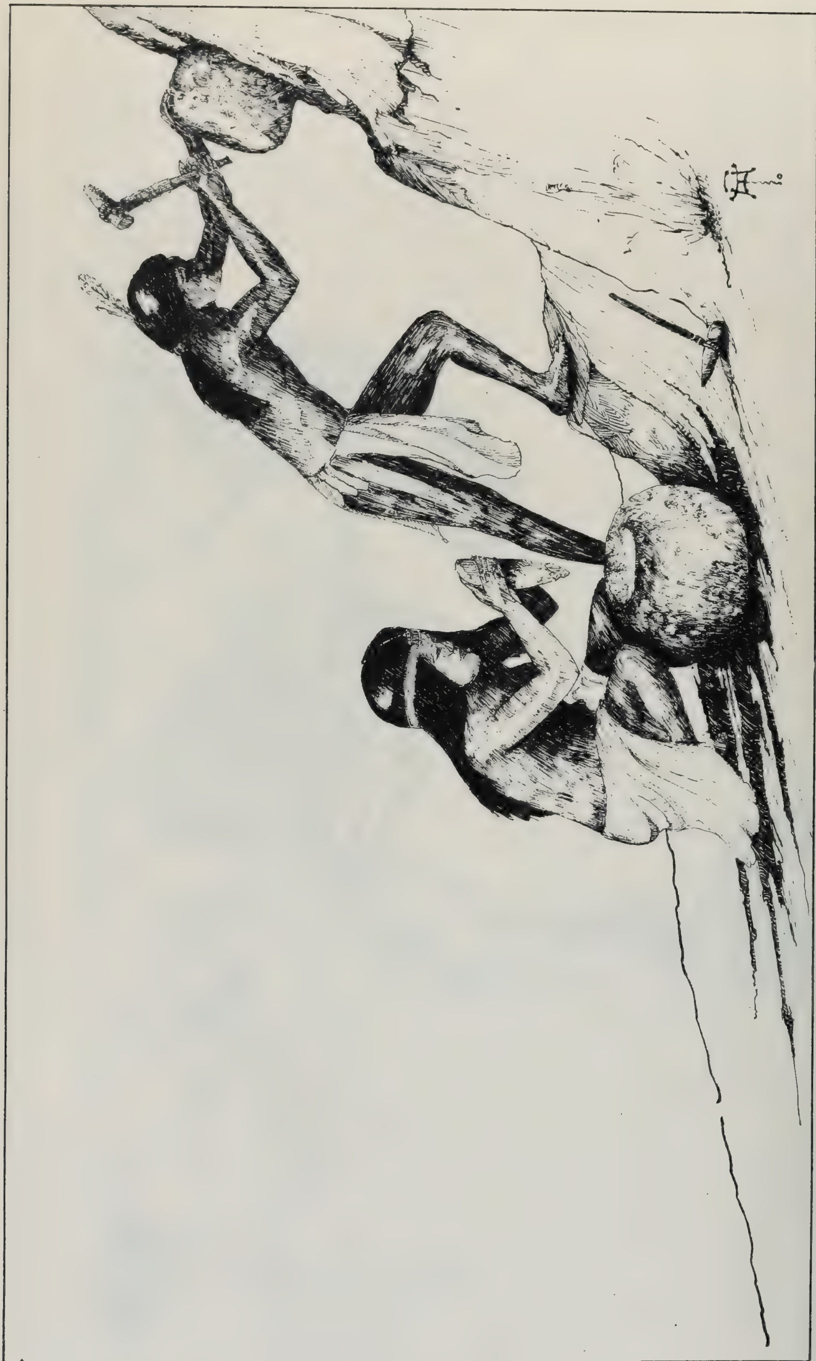


FIG. 2. Quarrying and working steatite at the Santa Catalina Island quarry. (After life group in the U. S. National Museum.)

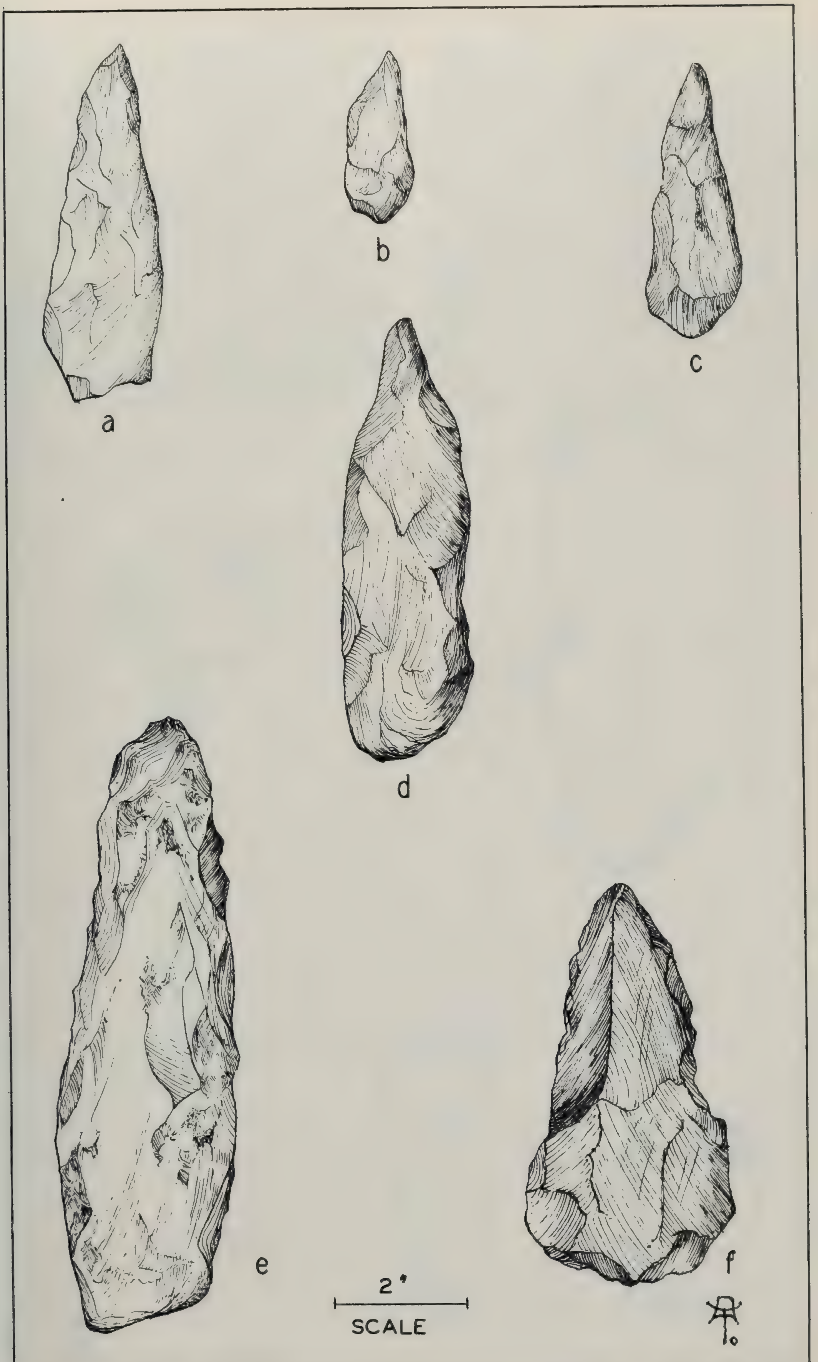


FIG. 3. Steatite quarry picks from Santa Catalina Island. (After Heye, 1921, and Schumacher, 1880.)

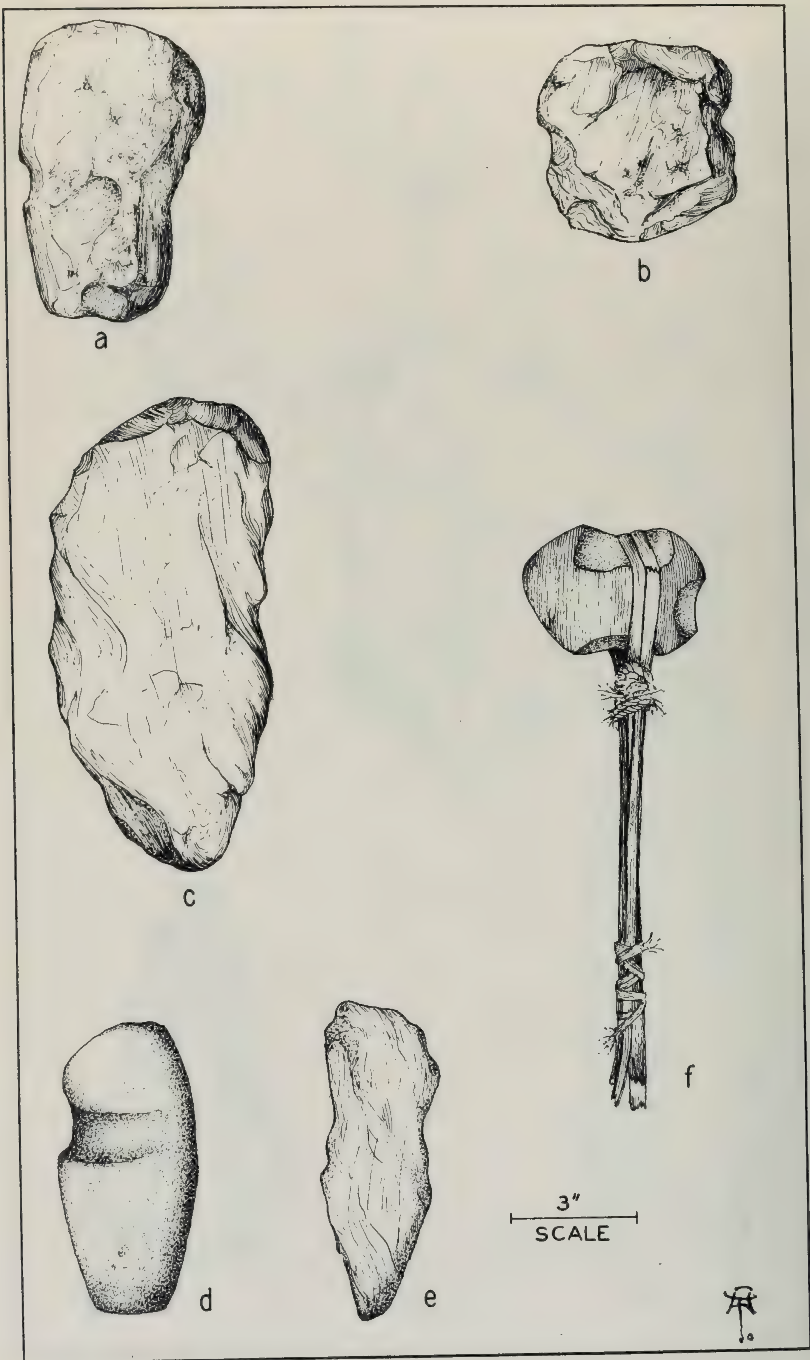


FIG. 4. Quarry tools: *a* to *e* from the San Bernardino County turquois localities (after M. Rogers, 1936); *f* from the nearby southern Nevada salt mines, shows hafting (after Harrington, 1927).

FIG. 5A-5B. Obsidian quarry at Borax Lake, Lake County (locality 4, map 1). *A,* obsidian outcrop surrounded by flaking refuse; *B,* roadcut showing depth of quarry refuse of at least 8 feet.

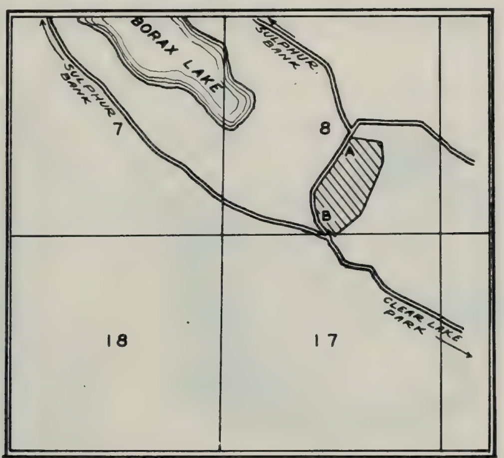


FIG. 6. Obsidian quarry and workshop area, Lake County, T. 13 N., R. 7 W., M. D. Hachured area shows extent of aboriginal activity. "A" is outcrop (fig. 5A), "B" is borrow pit showing obsidian flake rejectage in cutbank (fig. 5B).

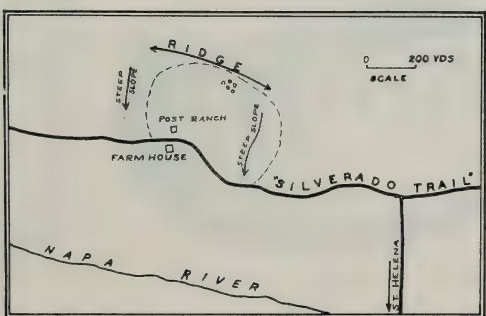


FIG. 7. Obsidian quarry (locality 2, map 1) 2.5 miles northwest of St. Helena, Napa County. Dotted line shows approximate extent of workshop area. Small circles near ridge denote aboriginal pits where nodules were excavated.

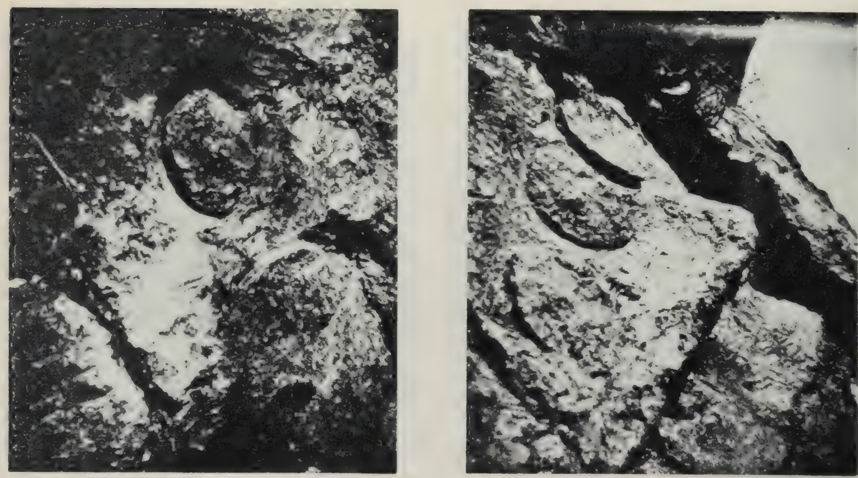


FIG. 8A-8B. Aboriginal steatite workings at Santa Catalina Island quarry (after Holmes, 1902). Circles represent spots where globular masses were undercut at the base.

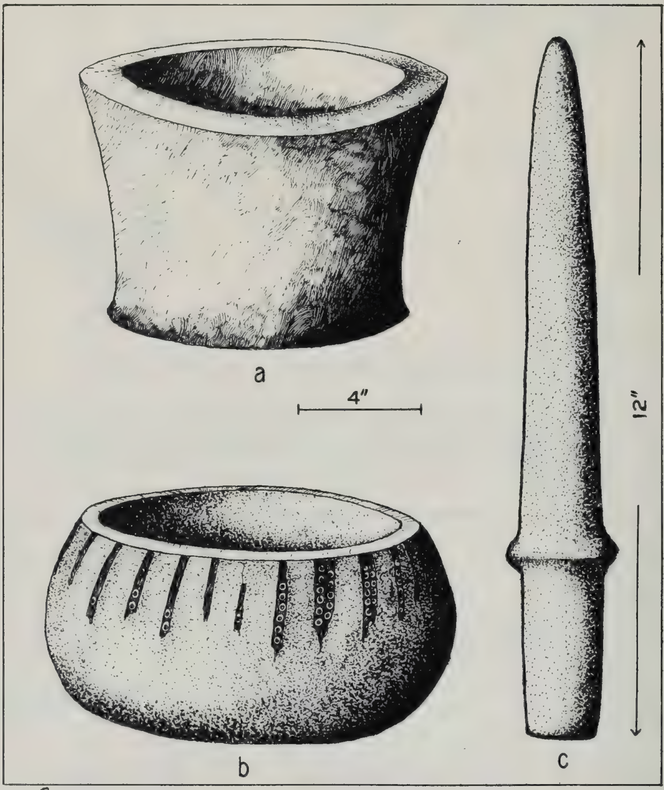


FIG. 9. *a*, Basalt mortar from Drake's Bay shellmound; *b*, sandstone bowl decorated with shell beads inlaid in asphaltum, Santa Barbara; *c*, stone pestle, Klamath River.

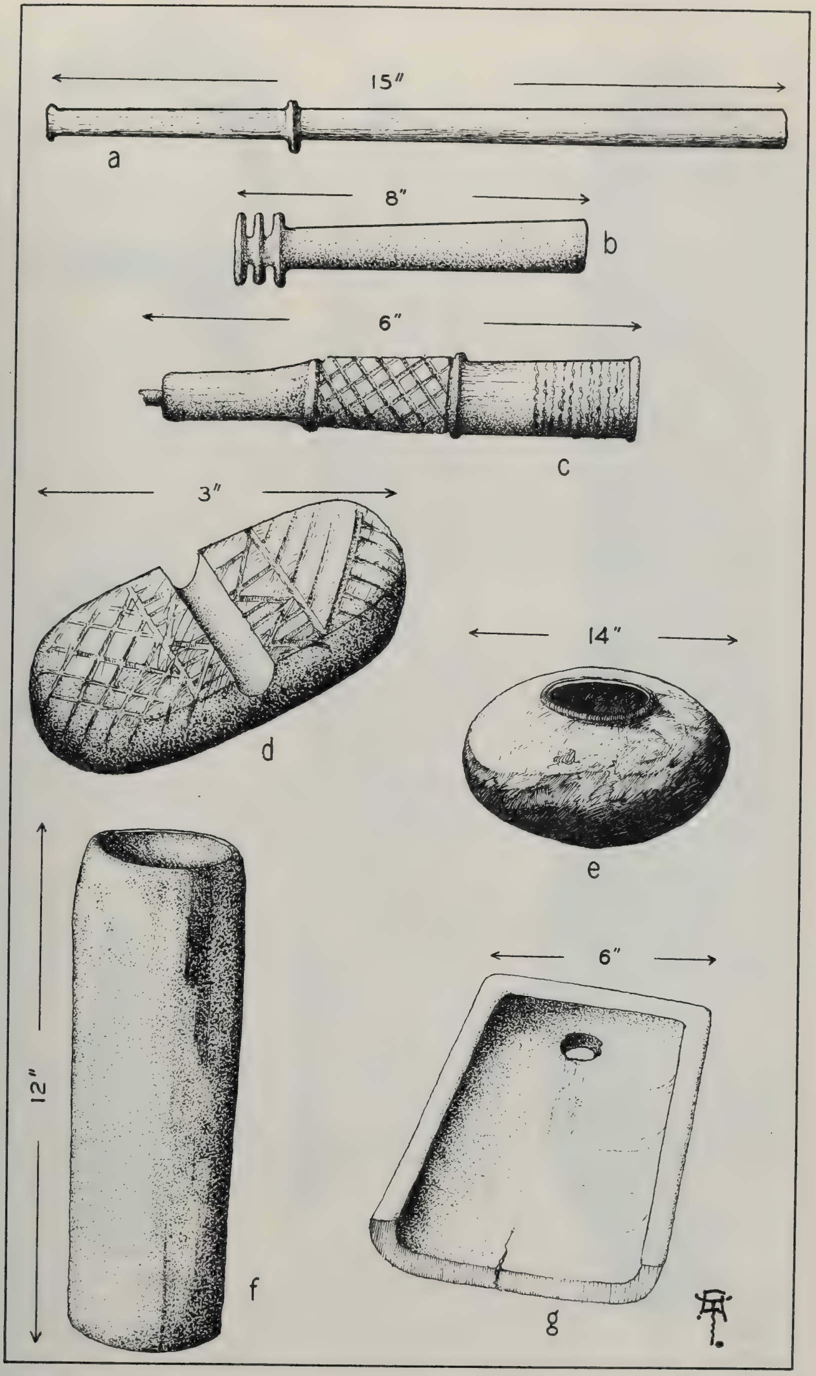


FIG. 10. Steatite artifacts: *a*, pipe, Modoc County; *b*, pipe, Sacramento Valley; *c*, pipe, Santa Barbara; *d*, arrowshaft straightener, San Bernardino County; *e*, small-mouthed, thin-walled olla, Santa Barbara; *f*, cylindrical jar, San Joaquin County; *g*, "comal," or frying pan, Santa Barbara.

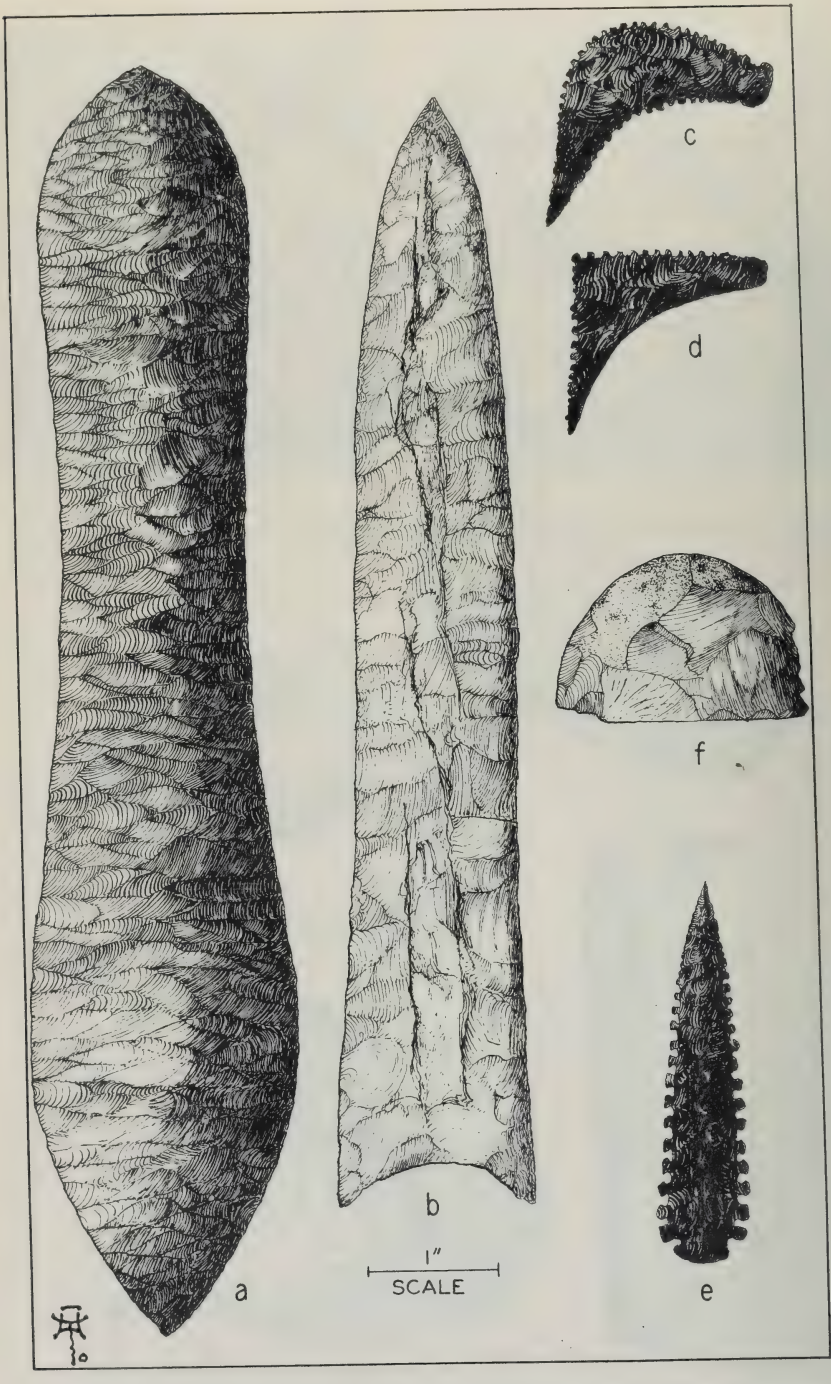


Fig. 11. Chipped implements: *a*, ceremonial obsidian blade, Klamath River; *b*, chert spearpoint, Santa Barbara; *c*, *d*, *e*, serrated obsidian artifacts, Sacramento County; *f*, hemispherical scraper of porphyry, San Diego County.

Locality 2: Forty miles south of Pinto Basin, Riverside County.

The jasper from this outcrop is a bright red. There is evidence of fairly extensive aboriginal workings (Campbell and Campbell, 1935, p. 49).

Locality 3: Forty miles north of Pinto Basin, San Bernardino County.

The jasper here is bright red. Artifacts made of material from localities 1 and 2 were found in the Pinto Basin region. (Campbell and Campbell, 1935, p. 49.)

Locality 4: Granite Mountain south of Death Valley, San Bernardino County.

In these mountains is a jasper ledge quarry which shows evidence of having been used by the Indians. The outcrop has been much hammered and chipped in order to secure material for making flaked tools. About an acre of surrounding ground is littered with jasper chunks, chips, and rejected artifacts. (G. F. Carter, personal observation.)

Flint

Locality 1: Table Mountain, near Oroville, Butte County.

The flint mine, worked since ancient times by the Maidu tribe, was considered a sacred spot by them. The belief that flint deposits were inhabited by spirits (ostensibly supernatural owners) is very widespread in America. Offerings of shell beads or pieces of dried meat were thrown into the cave by the Maidu to maintain accord with the spirits. Only as much flint was taken as could be detached by a man at one blow with a hammerstone. The Indian miner further observed ritual by crawling out of the flint mine backward. Failure to comply with these proscriptions would result in bad luck to the miner; the flint would not chip or his arrows would fail to kill. (Dixon, 1905, pp. 132-133; Kroeber, 1925, p. 418.) The Maidu Indians of the Sierras obtained obsidian from some northern tribe, probably the Achomawi. Local flint outcrops and volcanic rocks which lent themselves to flaking were utilized (Kroeber, 1925, pp. 399, 418).

Locality 2: Present settlement of Alcatraz, Santa Barbara County.

Near tide level is an extensive outcrop of flint nodules. The Chumash Indians made liberal use of this deposit, as attested by the tremendous accumulation of chipping waste and exhausted cores on the edge of the cliff which rises steeply behind the beach flint exposure (Rogers, D. D., 1929, p. 402).

Locality 3: One mile east of Tuolumne, on edge of Tuolumne River canyon, Tuolumne County.

A short tunnel about four feet high and ten feet long was driven in aboriginal times into the outcrop of gray flint. A waste and chipping rejectage dump lies in front of the flint workings. (R. F. Heizer, personal observation.)

Chalcedony

Locality 1: Redondo Beach, Los Angeles County (Ball, 1941, p. 56).

Locality 2: About 100 miles northwest of Pinto Basin, San Bernardino County (Campbell and Campbell, 1935, p. 49).

Petrified Wood

Locality 1: Pinto Mountain at junction of Davie's and International Wash on the United States-Mexico line, Imperial County.

Aboriginal use of this material extended over the whole area between Laguna Salada, Baja California to Borego Valley, San Diego County. Petrified wood, like glassy obsidian, is particularly amenable to fine pressure flaking, and the Pinto Mountain material is most commonly found as small, delicate arrowpoint artifacts (A. E. Treganza, personal observation).

Quartz Crystals

Quartz crystal lent itself well to chipping into arrow and spear points, and because of its hardness could be used as a flake cutting knife. The clear crystals seem to have been regarded by most of the California Indians as having magical virtues, and found service among the Yana Indians as luck charms (Sapir, 1908); in southern California they were used to tip sacred "wands" (Waterman, 1910, fig. 2); among the Wintu

they served as charmstones (Dubois, 1935); and the Nisenan of the American River region used them in ceremonies (Beals, 1933, pp. 387, 389). The most ancient sites of the Sacramento delta region yield human burials accompanied by great numbers of perfectly clear, flawless quartz crystals (Lillard, Heizer, and Fenenga, 1939, *passim*). The total number of these crystals runs to many hundreds, and it is obvious that this ancient population made a particular effort to secure them. The Mokelumne Hill locality, not far distant, was probably the source.

Locality 1: Sierra foothills, Calaveras County.

That limestone caves of the Sierra foothills were known to the Indians is evidenced by the finding of burials in a number of them. Quartz crystals in these caves and on the surface in this region are the logical source of the great numbers found in Indian graves along the eastern side of the Sacramento Valley (Schenck and Dawson, 1929, p. 392).

Locality 2: Vicinity of Placerville, near American River, El Dorado County.

The Mountain Maidu (southern Nisenan) used quartz crystal flakes for knives. They were obtained, according to Indian informants, from ledges in the vicinity (Voegelin, 1942, p. 193).

Locality 3: Near Pala, San Diego County.

The Luiseño Indians had an elaborate ceremonial cult which revolved around a deity called Chungichnich, and among the sacred objects used in ceremonies were smooth, round pebbles brought from the ocean beaches, and pieces of quartz crystals colored with lithia which were dug from the San Diego County tourmaline deposits (Du Bois, 1908, p. 99).

Asphaltum and Clay

(Map 5)

Asphaltum

The surface seepages of bitumen were known to the Indians, the first people to utilize the abundant petroleum resources of the State. Asphalt was dug from surface pits or collected from the southern California beaches in the form of lumps which had been exuded from submarine tar springs. Thus, from San Luis Obispo south, asphalt found wide aboriginal use for caulking plank canoes, and waterproofing baskets. It was also used as an adhesive for mending broken artifacts, or joining two pieces of material to form a composite tool (i.e., setting a flint knife blade in a wooden handle, or affixing a basketry hopper to a shallow seed-grinding mortar).

Locality 1: Mission San Luis Obispo region, San Luis Obispo County.

Pedro Fages in 1775 said,

> "At a distance of two leagues from this mission there are as many as eight springs of bitumen or thick black resin which they call *chapapote;* it is used chiefly by these natives for caulking their small water craft, and to pitch the vases and pitchers which the women make for holding water" (Heizer, 1940, p. 74).

Locality 2: Tajiguas Creek, Santa Barbara County.

This submarine seep was said in an 18th century Spanish exploration account to have been used by the Chumash Indians (Heizer, 1940, p. 74).

Locality 3: More's Landing at La Patera and Goleta Point, Santa Barbara County.

Father Pedro Font while at Goleta in 1776 said

> ". . . . . much tar which the sea throws up is found on the shores, sticking to the stones and dry. Little balls of fresh tar are also found. Perhaps there are springs of it which flow out into the sea, because yesterday on the way the odor of it was perceptible, and today . . the scent was as strong as that perceived in a ship or in a store of tarred ship tackle and ropes." (Heizer, 1940, p. 74.)

Locality 4: Santa Barbara, Santa Barbara County (Heizer, 1940, p. 74, fig. 34).

Locality 5: Carpenteria, Santa Barbara County (Heizer, 1940, p. 74, fig. 34).

Locality 6: Foot of Conejo Grade, Ventura County (Heizer, 1940, p. 74, fig. 34).

Locality 7: La Brea tar pits, Los Angeles County.

La Brea pit, subject of scientific exploitation to recover the great numbers of faunal remains imbedded in the mass, has produced evidence of man in the form of a human skeleton, an obsidian spear point, and various objects of wood believed by A. Woodward to represent foreshafts of spear-thrower darts (Hrdlicka, 1918; Woodward, 1937).

Locality 8: Mission San Gabriel, Los Angeles County (Heizer, 1940, p. 74, fig. 34).

Locality 9: Foothill region of southeastern Kern County.

In the archaeological remains of the southern San Joaquin Valley, Gifford and Schenck (1926, p. 53) encountered evidence of considerable aboriginal use of asphaltum. They suggest that the low hills bordering the area on the southeast and west, which have surface bitumen seeps, provided readily available sources for the material used by the Indians.

Locality 10: McKittrick tar seep, southwest of Buttonwillow Slough, Kern County (Hewes, 1941, p. 130).

Locality 11: Duxbury Point, Marin County.

Aboriginal use of the Duxbury Point asphaltum seeps is inferred from the presence in shellmounds in the San Francisco Bay region of aboriginal objects of decorative or utilitarian nature which bear shell beads inlaid in an asphaltum mastic (Schenck, 1926, p. 212).

Locality 12: West and south of Buena Vista Lake and in the vicinity of Maricopa and Hazelton, Kern County.

These localities probably provided the asphaltum used by the ancient inhabitants of the Buena Vista Lake region, from whose old living mounds have come quantities of this material (Wedel, 1941, pp. 37-38).

Clay

Clays were used chiefly by those tribes which knew the art of making fired pottery. Only the native groups of the extreme southern San Joaquin Valley and of southern California proper practiced the ceramic arts. In the southern Sacramento Valley where the terrain is composed solely of alluvial soil the ingenious Indians made baked clay "balls" which were used as substitutes for rocks in stone boiling (Schenck and Dawson, 1929, pp. 360-368; Heizer, 1937). The following list represents for the most part the known localities where the Indians dug clay from which pottery vessels were fashioned.

Locality 1: Dunlop, Fresno County.

The Yokuts tribe of the San Joaquin Valley had a clay pit at this place (Gayton, 1929, p. 241).

Locality 2: Somerton Indian Reservation, just south of the United States—Mexico boundary line.

The Cocopa Indians obtained clay from a flat field on the reservation. The clay stratum lay a few inches beneath the surface. A stick about eighteen inches long held in both hands was used for digging (Gifford, 1933, p. 318).

Locality 3: Slopes of Palomar Mountain, San Diego County.

The Luiseño Indians dug out a white clay which was thinned with water and the residue became very white when dry. It was used as face paint in the girls' adolescence ceremony. (Strong, 1929, p. 298.)

Locality 4: Mason Valley, San Diego County.

A fine sedimentary clay deposit in this valley furnished the Diegueño Indians with potters clay (M. J. Rogers, 1936, p. 4).

Locality 5: Manzanita, San Diego County.

Similar to the deposit in locality 4 (M. J. Rogers, 1936, p. 4).

Locality 6: Old lake-bottom deposits of central Colorado Desert, Imperial County.

These clays, or more strictly, alluvium deposits produce a brittle, much harder, lighter weight, and lighter colored ceramic ware (localities 6-9 incl.) than do the residual deposits derived from the breakdown and weathering of granite outcrops (localities 3-5 incl.). Crushed rock is added to the clay as tempering to prevent the vessel from cracking when fired. At times mica (muscovite) was used for the same purpose. (M. J. Rogers, 1936, p. 24; Treganza, 1942, pp. 157-159.)

Locality 7: Floodplain of the Colorado River (M. J. Rogers, 1936, p. 30).

Locality 8: Upper terraces of the Colorado River, Imperial County (M. J. Rogers, 1936, p. 30; Gifford, 1931, p. 42).

Locality 9: Base of Parker Mesa, Arizona side of the Colorado River (M. J. Rogers, 1936, p. 36).

Locality 10: Borego Valley, San Diego County (H. Sharp, personal observation).

Locality 11: Dos Cabazes Springs, San Diego County.

The Diegueño Indian women secured potters clay from near these springs. Each woman of this tribe had her own clay deposit which "worked good for her and liked her." For her, other clays would form pottery which would crack (H. Sharp, personal observation). Perhaps there is a rational explanation for this belief, since a woman learned the potter's art from her mother and used the same family clay deposit. A successful technique was built up around a particular clay which would not apply to a different clay with different reactions to drying, tempering, and firing. Technological traditions which were individual were probably largely determined, or at least maintained in perpetuity, by the physical properties of the raw material.

Locality 12: Spring Valley, 10 miles east of San Diego, San Diego County.

Diegueño Indian women are known to have regarded potters clay from this valley so highly that they traveled 60 miles to obtain it (H. Sharp, personal observation).

Locality 13: White Water River at head of Cahuilla Valley, Riverside County.

It was not necessary to add tempering material (crushed rock or shell) to this clay, since it made good pottery in its natural state (Schumacher, 1880, pp. 521-23).

Locality 14: Jewel Valley near the San Diego and Arizona railroad, about 6 miles west of Jacumba, San Diego County.

A residual granite clay deposit used by the Southern Diegueño Indians (H. Sharp, personal observation).

Locality 15: Near Fish Springs, about 5 miles south of Big Pine, Inyo County.

A reddish clay used for making pottery was dug here by the Owens Valley Paiute (Steward, 1933, pp. 266-67).

Locality 16: Baker Creek, just west of Big Pine, Inyo County.

A decomposed granite deposit with one or two feet of kaolin and small hard crystals was widely used by the local Indians, since it produced excellent pottery. The crystals (feldspar?) furnished tempering grit (Steward, 1933, pp. 266-267).

Locality 17: Potter Valley, Mendocino County.

A red ferric dirt or clay was dug from a pit in the valley and used as "Indian baking powder" in making acorn bread. The chemical effect of this process is discussed in the section on *The Indian as a Mineralogist and Chemist* (Stewart, 1943, p. 40). Chesnut (1902, p. 339) states that this red clay contains 10 percent FeO_2 by weight.

Miscellaneous Materials

(Map 6)

Magnesite

The Southeastern Pomo of the lower end of Clear Lake held a monopoly on the two magnesite quarries which appear to have served all central California with material for beads. Shell disk beads were the ''small change'' currency of the central part of the State, but magnesite cylinders (from one-quarter to two inches in diameter and one-half to four inches in length), which were made only by the Lake County Pomo, were the equivalent of our gold pieces. Indeed most Indians volunteer this specific translation of their value, calling the cylinders ''Indian

gold'' (Kroeber, 1925, p. 249). An inch-long cylinder in post- Caucasian times was worth five dollars to a Maidu Indian living east of the Sacramento River. Larger pieces had correspondingly higher values. Every tribe within a radius of 150 miles possessed and treasured these valuable magnesite cylinders. With the coming of the whites and acquisition of the pump drill, steel drill point, and file, production of magnesite cylinders was stimulated, and the native market was flooded by the product with a resultant decline in value.

The magnesite was broken out of the deposit with rocks. The rough chunks thus disengaged were then buried under a fire to cause the mass to split and break, and to impart a pleasing color which ranged from pink to brick red to chocolate brown. The small colored pieces were then ready for shaping into cylinders.

Locality 1: Sulphur Bank, Clear Lake, Lake County (Ball, 1941, pp. 39, 57; Gifford, 1926, p. 378; Loeb, 1926, p. 178).

Locality 2: White Buttes, near Cache Creek, Lake County (Kroeber, 1925, p. 249; Stewart, 1943, p. 44).

Turquois

The only aboriginal turquois mines in California are in the Mojave Sink region of southern California. The local desert dwellers did not carry out the mining operations. The mines were worked by the higher cultured Pueblo peoples from the south (New Mexico and Arizona) who made expeditions in force to the turquois localities of California. This we know from the distinctive types of artifacts associated with the quarries. The painted pottery, grooved stone axes, and hammers are distinctive of the Puebloan type of culture farther south and not of the simple desert Indians of California; hence we may attribute their presence to intrusive groups of Puebloan turquois miners from across the Colorado River.

Reports of prospectors in 1898 led to a rather elaborate expedition being sent out by the *San Francisco Call.* The scientific observer was Gustav Eisen, a prominent member of the California Academy of Sciences who published an excellent account of his observations in the *Call,* for March 18, 1898. Commercial mining soon followed, and the famous Toltec and Himalaya turquois mines were developed. Thirty years after Eisen's inspection the San Diego Museum published the results of a careful modern archaeological reconnaissance of the aboriginal turquois workings and associated remains (M. J. Rogers, 1929A).

The three main turquois localities are in northeastern San Bernardino County in the Turquoise Mountains near the main highway from Barstow to Las Vegas. The aboriginal remains consist of the mining pits, natural shelter caves with smoke-blackened walls where the miners lived, pecked petroglyphs on the rock walls and boulders, scattered potsherds in which the ancient miners probably cooked their food, and crude mining tools—stone hammers and picks, and tortoise carapace ''shovels'' for excavating the crushed rock (Eisen, 1898; Kunz, 1899, pp. 557-600; Kunz, 1905, pp. 12, 107-109, 152-153; M. J. Rogers, 1929A; Dunn, 1930).

Locality 1: Three miles east of Toltec turquois mines, T. 16 N., R. 10 E., S. B., San Bernardino County.

This series of aboriginal pits is called by M. Rogers (1929A) the Middle Group. The Toltec and Himalaya groups lie to the west and east, respectively, and are separated by an eight-mile gap. The terrain is somewhat rugged and dissected by

small ravines. The Indian miners ran open cuts along the steep sides of these ravines in following the thin turquois veins. No less than 20 separate aboriginal workings were noted at the Middle Group by Rogers' field party. Associated with the workings were the old stone mining tools such as mauls, picks, and axes.

Locality 2: Toltec turquois mines, San Bernardino County, T. 16 N., R. 10 E., S. B., San Bernardino County.

The terrain here is rugged and gullied as at the Middle Group. Here also the Indian turquois miners ran opencuts along the gully banks where the veins were exposed at the surface. The old workings have been largely obliterated by modern operations, many of the latter simply being continuations of the Indians' excavations. A total of 200 aboriginal pits at the Toltec locality is given by M. J. Rogers (1929A, p. 5).

Locality 3: Himalaya turquois mines, T. 16 N., R. 11 E., S. B., San Bernardino County.

The terrain of this site is in the nature of a plateau with a less degraded surface which has better preserved the aboriginal workings. Erosion has carried the crushed rock dumps back into the pits so that they now appear like miniature craters dotting the surface of the plateau. Rogers counted 50 pits at the Himalaya locality, among which was one measuring 30 feet in diameter and with a fill depth of over 5 feet. One aboriginal working which was cleaned out measured 30 feet long, 12 feet wide, and 12 feet deep with numerous short drifts extending out where small stringers were followed.

Tortoise carapace "shovels" or scoops, and stone mining tools are found in quantity in and around the old workings (M. J. Rogers, 1929A).

Locality 4: Near Granite Wells, 22 miles east of Johannesburg, San Bernardino County (M. J. Rogers, 1929A, p. 2).

Locality 5: Death Valley, Inyo County (Kunz, 1898, p. 504).

Chrysocolla

Locality 1: Turquoise Mountains, 10 miles northeast of Silver Lake, San Bernardino County.

In a small cave which had been used as an occupation site by the ancient turquois miners was found a chunk of chrysocolla. Since this mineral is closely associated with turquois in the nearby mines, it is probable the piece came from there. (M. J. Rogers, 1929A, p. 7).

Chrysoprase

Locality 1: Venice Mill, 8 miles east of Visalia, Tulare County.

Near the modern commercial mines are old depressions which are thought to be aboriginal pits.

Sterrett (1911, pp. 753-54) says,

> "Around some of the chrysoprase deposits are shallow pits or depressions and small dumplike mounds which resemble the ancient workings of the Aztecs seen around the turquoise mines of the Southwestern States." [2]

Since jasper occurs abundantly at the Venice Hill chrysoprase locality (Sterrett, 1911, p. 752), it seems most probable that the old pits represent workings directed toward recovery of jasper which was used for arrow points. Jasper artifacts occur commonly in local mounds and chrysoprase artifacts do not.

Locality 2: Three-quarters of a mile north of Lindsay, Tulare County.

Here, as at locality 1, old workings, presumed to be attributable to Indians, occur in the vicinity of modern commercial chrysoprase mines. Sterrett did not say what material the Indians were recovering, but it was probably jasper, though chrysoprase cannot be ruled out. It is to be hoped that some observer may visit these old workings and clear up the problem.

Sterrett (1911, p. 755) says,

> "There are a few small pitlike depressions or holes and old dumps in or near the cherty serpentine outcrops on the south side of the hill. These resemble the working of the Aztecs seen around ancient turquoise mines in the Southwest."

[2] The Aztecs were local Indians. One commonly finds reference to "Aztecs" and "ancient Aztec mines" in the Southwest, but these people of the Valley of Mexico did not conduct mining operations within the present limits of the United States.

Tourmaline

Locality 1: Mesa Grande, San Diego County.

These are the famous gem tourmaline mines which were first worked by the Indians. Local natives are said to have helped rediscover some of the deposits. That the ancient Indians knew and used the Mesa Grande tourmalines is proven by the presence of this mineral in Indian graves. (Kunz, 1905, pp. 23, 55, 56). Du Bois (1908, p. 99) notes that the Luiseño Indians used tourmaline crystals dug from these deposits in their Chungichnich ceremony. It was regarded by them, because of its religious association, as a sacred substance.

Galena

Locality 1: Santa Catalina Island.

In 1792 a learned Spanish explorer, José Longinos Martinez, said,

> "The natives in the vicinity of San Gabriel (Mission) are accustomed to carry small stones, which they acquire at a great price from the Indians who bring them from the Island of Los Angeles (Santa Catalina). These stones are of lead in galena (*ferrulata*) with silver."

The stones were carried as magical charms and not for their metal value (Simpson, 1938). The deposit from which this ore came was probably the ore in Silver Canyon (Randolph, 1935, pp. 7-8).

The Owens Valley Paiute made gray paint from finely ground galena, but the locality from which they secured the material is not known (Steward, 1933, p. 277).

Granite

There is only one locality listed from which the Indians secured granite. This rock, however, was very extensively used by the California Indians for mortars and pestles, as a survey of any large museum collection will demonstrate. All of the Sierran tribes knew and used granite for seed grinding instruments. River boulders which were already partially shaped by nature were often utilized, since an elongated cobble could be used as a pestle and a round boulder needed only a starting hole pecked in it for the grinding cavity. Most California residents have seen flat exposures of granite in the Sierras which are pitted with mortar holes whose number in some cases runs into scores and even hundreds. Granite, a resistant stone, was favored for these aboriginal acorn milling sites, which are known to anthropologists by the term ''bedrock mortar sites.''

Locality 1: Jacumba, San Diego County.

The Kamia tribe which formerly occupied the Imperial Valley secured granite here for mortars and pestles (Gifford, 1931, p. 41).

Porphyry

Locality 1: Jacumba Valley, San Diego County.

Large float boulders whose geologic origin is unknown occur in this valley. Partially buried boulders of large size have had the entire exposed surface chipped off by Indians who found the material an excellent one for large flaked blades and scrapers. Chipped artifacts of this float porphyry occur both north and south of Jacumba Valley. (A. E. Treganza, personal observation.)

Locality 2: Coastal plateau, San Diego County.

A gravel stratum composed predominantly of porphyries, caps the coastal plateau between Orange County and the United States-Mexican boundary line. These gravels were the source of stone materials for flaked implements of the early post-Pleistocene populations of southern California.

In the canyon walls where the San Dieguito River cuts through the Coast Range west of Lake Hodges, latite and felsite beds are exposed. These strata were quarried for implement material by the early coast dwellers (M. J. Rogers, 1929B, p. 460).

Pumice

Locality 1: Hat Creek, Shasta County.

The Western Achomawi and Atsugewi tribes used chunks of pumice for smoothing arrow shafts. Pumice is abundant in this region, and no particular quarry was favored (Voegelin, 1942, p. 191). All of the Indians of northeastern California used pumice as an abrasive.

Locality 2: "Pumice Butte," near Obsidian Butte on the east side of Salton Sea, Imperial County.

This volcanic butte probably provided the pumice material for many of the abrasive artifacts found as far west as the Jacumba Valley. (A. E. Treganza, personal observation.)

Sandstone

Sandstone and allied sedimentary rocks were very extensively used by the California Indians. The harder, more resistant varieties were preferred since they gave better and longer use. Flat grinding slabs (metates) and mortars were made of sandstone by many California Indian tribes. In particular, the Chumash Indians of Santa Barbara had available a light-gray, tough sandstone which they fashioned into large ceremonial mortars. Some of these weigh several hundred pounds and were quite perfectly formed (fig. 9) and decorated with rows of shell beads inlaid in an asphaltum mastic.

The Pomo Indians made tremendous quantities of disk beads of clam shell (*Saxidomus nuttalli*). The process of manufacture consisted of chipping out rough shell blanks, drilling them, stringing the blanks on a long twig and rolling them on edge on a flat sandstone slab. Sandstone slabs used for this purpose are common finds at old Pomo village sites. The large number of shell beads made by the Pomo by this laborious method is shown by the fact that this tribe had a highly developed counting system employing units and multiples of 20. In early white contact days 400 clamshell disk beads sold for $2.50. After introduction of the pump drill the value of 400 beads fell to $1.00. Familiarity with large numbers is illustrated in one recorded tale in which a medicine man paid an indemnity of 40,000 shell beads (Kroeber, 1925, p. 256).

Locality 1: Foothills of Sierra de Juarez Mountains, Imperial County.

Float sandstone in flat slab form is abundant in this region. The Indians selected suitable detached slabs and used them for flat metates for grinding seeds. (Holmes, 1902, p. 185; A. E. Treganza, personal observation.)

Schist

Locality 1: Wildcat Canyon, Contra Costa County.

Near the mouth of Wildcat Canyon in the stream bed are greenstone schist boulders, some of them very large. Nearby Indian shellmounds in the vicinity of Richmond and Berkeley yield numerous artifacts made of this material, and there seems little doubt that the Wildcat Canyon float material was the source. (Loud, 1924, p. 367.)

Slate

Slate is another rock which was very extensively used by the California tribes. A hard, close-grained variety was employed by the ancient peoples of the Sacramento-San Joaquin delta region for ornamental pendants, since in finished form it assumed a fair degree of polish. Other sources of slate were apparently known to the same populations, judging from the presence of thin edge-chipped blades whose flat surfaces were formed by the parallel cleavage planes. Archaeological sites throughout the State generally yield worked (polished or chipped) slate artifacts.

Locality 1: Santa Catalina Island, near the pass above Pots Valley.

An extensive slate exposure where tools were made for quarrying the nearby Catalina soapstone is described by Schumacher. The slate was first roughly broken out of the outcrop, then pieces suitable for quarry picks and chisels were selected and trimmed down into completed form. One of these implements is shown on figure 3 (Schumacher, 1880).

White Chalk

Locality 1: Vicinity of Santa Barbara, Santa Barbara County.

Shellmound graves yield quantities of white chalk (kaolin?), used as paint by the Indians. According to Harrington (1926, p. 102) there are deposits in the immediate locality from which this was obtainable.

Locality 2: Springs at Springfield, Tuolumne County.

The Central Miwok Indians obtained a white "chalk" called *walanasu* from the bottom of springs at Springfield (Barrett and Gifford, 1933, p. 224).

Locality 3: East of Owens Valley, Inyo County.

The Shoshoni Indians had a lemon-yellow chalk deposit in their territory. They mined it and traded it to their western neighbors, the Owens Valley Paiute (Steward, 1933, p. 276).

Locality 4: Fish Springs Dam, eastern end of Poverty Hills, Inyo County.

White chalk was secured here by the Owens Valley Paiute (Steward, 1933, p. 276).

Locality 5: Bidwell Mountain, Modoc County.

A soft, brownish-tan "chalk rock" was dug from a deposit on this mountain. It was crushed, soaked in water and drained. After this process it was white, the soluble brown stain having been leached out. It was used as face paint after being moistened with the tongue (Kelly, 1932, p. 116).

Salt

Not all of the California Indians used salt with their food. Most coastal tribes ate sea plants and animals (kelp, fish, mollusks) which supplied necessary salt, but they might in addition evaporate sea water to collect salt (Kroeber, 1941, pp. 1-6). The interior tribes either got salt from the coastal groups or exploited some local salt spring.

In north-central California there was a far-famed salt seepage near the village of *Cheetido,* Big Stony Creek, which was the resort of most of the tribes within a radius of 75 miles. This was neutral ground, where enemy tribes might find themselves together, but were forced by custom to take no action against one another (Loeb, 1926, p. 195). The Stonyford seepage was owned, however, by the Northeastern Pomo, who were extremely jealous of their legal property right which they considered duly recognized if a salt expedition force asked permission to collect salt and presented the Pomo with suitable gifts (Loeb, 1926, p. 195). A number of battles were fought between the Northeastern Pomo and outside groups over unauthorized use of the Stonyford salt deposit. These have become known in ethnographic reports as the Pomo Salt Wars. The account of one of these "wars" runs as follows: The Potter Valley Pomo had long been accustomed to cross the mountains and purchase salt from their Northeastern Pomo neighbors. Once a party of Potter Valley people attempted to take salt secretly, but were discovered, attacked, and the party nearly destroyed. The Potter Valley people killed some Northeastern Pomo who happened to be in their territory at the time for revenge, and then changed their salt source to the ocean as the wisest course (Kroeber, 1925, p. 236; Loeb, 1926, p. 174; Stewart, 1943, pp. 39, 43).

Locality 1: Between Somerton and Yuma, on Mexican side of International boundary.

Rock salt was obtained in a pond measuring 40 yards in diameter by the Cocopa Indians who called the locality *eserawawa* (Gifford, 1933, p. 269).

Locality 2: Southern edge of Salton Sink, Imperial County.

The Kamia Indians leached salt-impregnated earth of the Salton Sink shore and crystallized the salt by boiling. Other salt sources were in Baja California 2 or 3 miles south of Algadones, and Baja California south of Indian Wells. (Gifford, 1931, pp. 4, 24-25.) The Diegueño and Akwaala Indians living on and south of the Mexican boundary line knew of spots near the coast where free salt could be scraped up (Drucker, 1941, p. 172).

Locality 3: Salt Spring Valley, 3 miles north of Stonyford and 1 mile west of Big Stony Creek, Glenn County.

This is the widely used salt seepage of the Northeastern Pomo near their village named *Cheetido.* This seep of salt-impregnated water covers about an acre. The top crust was scraped off in summer, stored crude or refined on the spot by dissolving in water and gathering the salt after evaporation (Barrett, 1908, pp. 240-244; Kroeber, 1925, p. 236). There are other similar salt seeps in the foothills of Glenn and Colusa Counties which were known to the Indians.

The Kato tribe obtained salt from deposits just north of Westport, Mendocino County (Loeb, 1932, p. 47). Near the southern head of Cottonwood Creek is said to be a rock salt deposit from which the Clear Lake Pomo got salt (Gibbs, 1860, p. 109).

Locality 4: Near Marysville Buttes, Sutter County.

The Northern Maidu obtained salt "from deposits of some size near the Marysville Buttes" (Dixon, 1905, p. 191).

Locality 5: Saline Valley, east of Independence, Inyo County.

Great quantities of salt were gathered in this area by the Shoshoni tribe who in turn traded it to the Paiute of Owens Valley in exchange for shell beads. Some of this salt found its way into the valley region of south-central California over the mountains by way of Indian trade routes (Steward, 1938, p. 78; Steward, 1933, p. 250).

Locality 6: Near Rocklin, Placer County.

Salt springs yielded salt for table use to the Nisenan (Southern Maidu) Indians (Beals, 1933, p. 354).

Locality 7: Near Cool on the Knickerbocker Ranch.

Salt-marsh pools furnished salt to the local Indians in this area. A group owning salt springs guarded it against unauthorized use by foreigners, since salt was a valuable trade commodity and a surplus constituted an economic asset. (Beals, 1933, p. 365; Waring, 1915, p. 300).

Locality 8: South of Folsom, Sacramento County.

At this locality, salt spring water was boiled to evaporate for salt crystals (Beals, 1933, p. 254).

Locality 9: Near Lincoln, Placer County.

Salt springs, as seems to be the rule in this general locality, were the source of salt used for culinary purposes (Beals, 1933, p. 254).

Locality 10: Klondike Lake, Inyo County.

Salt was scraped off the surface and used without any further refining (Steward, 1933, p. 250).

Locality 11: 40 miles east of Alderpoint near northern Yolla-bolly (Snow Mountain), Trinity County.

The Lassik Indians got salt at this place, but generally went at night and "stole" it (Essene, 1942, p. 56).

MINERALS OF UNKNOWN SOURCE

Graphite

Graphite was used by the Indians of the southern California desert region for black face paint (Strong, 1929, p. 298, fn. 522; Waterman, 1910, p. 313).

Mica

Excavations in a shell mound on the west shore of Tomales Bay in 1940 and 1941 by the University of California yielded numerous human

burials accompanied by ornaments made of clear sheet muscovite measuring from one-half by one to three by three inches. These were drilled for suspension. No mineral locality is known for this material, but the occurrence is probably nearby, since this site produced so many clear mica ornaments, and neighboring sites had none.

A dense, greenish biotite was used in the lower Sacramento Valley region in ancient times for ornaments. No source is known.

Alabaster

Certain "Early Sacramento" period archaeological sites in the lower Mokelumne-Cosumnes River region have produced "charmstones" of translucent, banded alabaster. The source of this material is probably the limestone caves of the Sierra Nevada directly to the east, though thermal spring deposits in Solano County might have been used (Waring, 1915, p. 162). The same ancient valley population, the oldest of which there is any record in the area, probably gathered quartz crystals in this Sierra region (locality 1, map 4).

Malachite

Archaeologists occasionally turn up bits of bright green malachite in ancient sites of the lower Sacramento Valley. The Copperopolis mineral locality immediately to the east was probably the source of this green pigment.

Zincblende (Sphalerite)

Pieces of this mineral were recovered from ancient mounds in the Stockton-Lodi region by E. J. Dawson (Schenck and Dawson, 1929, p. 394). Since it is difficult to imagine any practical use this particular mineral might serve the Indian it appears probable that almost any mineral specimen of striking optical appearance (color, crystalline structure) which an Indian encountered while foraging for food might be picked up and carried home as a "curiosity." At any rate, this hypothesis explains the not uncommon occurrence in archaeological sites of fossil shells, odd-shaped concretions, vertebrate fossils, and unworked mineral specimens.

This discussion naturally brings up the question of why the California Indians were not interested in gold. Nearly all the peoples in the vast area from Argentina and Chile north to Sinaloa, Mexico or perhaps up to the Gila River, Arizona, were acquainted with metallurgy or smelted metals (copper and bronze). Many peoples of the eastern United States, and the western tribes north of Puget Sound, used native copper which they worked by cold-hammering. All these native groups were eager to secure iron from the first Europeans, a substance they immediately recognized as a tool material superior in durability and hardness to copper, whether a smelted alloy product or cold hammered native metal. The California Indians on the other hand, neither knew nor used metals before the Spanish occupation, and when they first saw European metal tools were not unduly impressed or covetous. This profound disinterest in metals extended, of course, to native gold which the Sierran tribes must have seen many times. But it was useless and very heavy, and one may suppose a mountain Indian would rather carry around something of a more useful nature than a weighty nugget.

ROCKS, MINERALS, AND DECORATIVE STONES USED BY CALIFORNIA INDIANS †

Material	*Tribe or region*	*Use*
Agate	Southern California	Arrowpoints
Agatized wood	San Diego and Imperial County	Arrowpoints
Actinolite	San Francisco Bay region	Charm stones, ceremonial
Alabaster	Central California	Charm stones, ceremonial
*Amazonstone		
Amethyst	Santa Barbara Channel region	Beads
Amphibolite schist	Sacramento Valley region	Ceremonial plummets
Basaltic rocks	Universal	Metates and mortars
Biotite	Sacramento delta region	Ornaments
Calcite	San Diego, Imperial County	Beads
*Carnelian		
Chalcedony	Southern California	Arrowpoints, scrapers
*Chalcopyrite		
Chert	Universal	Arrowpoints, scrapers
Cinnabar	San Jose, New Almaden mine, Death Valley	Paint pigment
Chlorite schist	San Francisco Bay region	Charm stones
Chrysocolla	San Bernardino County	Unknown
Chrysotile asbestos	Sacramento Valley region	Ceremonial
Chrysoprase	Southern San Joaquin Valley	Unknown
Dolomite	Imperial County	Mortars
*Feldspar, white		
*Feldspar, pink		
Flint	Southern California	Arrowpoints
*Fluorite		
Galena	Santa Catalina Island, Owens Valley	Ceremonial amulets, paint
Garnet	Imperial County	Unknown
Gilsonite	Santa Barbara County	Ceremonial (?)
Gypsum	Southern California	Ornaments
Granite	Universal	Mortars and pestles
Graphite	Southern California desert	Body paint
Halite	Universal	Food
Hematite	Universal	Paint pigment
Jasper	Southern and central California	Arrowpoints, scrapers
Limonite	Universal	Paint pigment
Magnesian mica	Santa Barbara, Sacramento Valley regions	Bowls and jars
Magnesite	Pomo tribe of Lake County	Money and decoration
Malachite	Sacramento Valley region	Paint pigment
Manganese	Imperial County, San Diego County and Mono Lake	Paint pigment
Moss agate		
Muscovite	San Francisco and Drakes Bay areas	Ornaments
Obsidian	Universal	Arrowpoints and chipped tools
*Onyx		
Opal	Southern California	Arrowpoints
Porphyry	Southern California	Spearpoints
Pumice	Universal	Abrasive
*Pyrite		
Quartz crystals	Central and southern California	Ceremonial, arrowpoints
Quartz, rose	San Diego and Imperial County	Arrowpoints
*Quartz, smoky		

† After Ball, 1941; supplemented by the present authors.
* Listed by Ball, 1941; as used by Indians.

ROCKS, MINERALS, AND DECORATIVE STONES USED BY CALIFORNIA INDIANS—Continued

Material	*Tribe or region*	*Use*
Sandstone	Universal	Metates, mortars, abrasive
Schist (micaceous)	Southern California	Arrow straighteners
Steatite	Universal	Vessels, pipes, ornament arrow straighteners
Serpentine	San Francisco Bay region	Charm stones
Tourmaline	Mesa Grande, San Diego County	Ornaments
Turquois	San Bernardino, Inyo Counties	Ornaments
Zincblende (sphalerite)	Sacramento Valley region	Ceremonial

COMPARISON OF CALIFORNIA AND NORTH AMERICAN ABORIGINAL MINING

A recent paper by S. A. Ball (1941, pp. 56-59) lists 254 aboriginal mines and quarry sites in North America, not including 29 California localities. The authors have shown on maps a total of 142 sites within the boundaries of California. These comparative totals do not signify that the California Indians can be credited with 55 percent of the total aboriginal mineral exploitation in North America; rather they suggest that many North American Indian quarry and mine sites are still unrecorded. Ball did not list clays (17 California localities), asphaltum (12 localities), or certain other materials such as flint, granite, porphyry, pumice, sandstone, schist, chalk, and salt (33 California localities). When these 62 localities are subtracted from the authors' grand total, the California-North American percentage falls to 31. It is not probable that the California Indians would prove to have used more stone per capita than the Indians of any other area, if we had comparable ethnographic data for the rest of North America. On the other hand the California Indians appear to have used stone for tools, ornaments and weapons as fully as other tribes, so their exploitation of lithic resources may perhaps be considered a North American average, subject in extension or interpolation to areal adjustment on the basis of population and available or potential lithic resources.

In general the local tribal groups in North America used their own outcrops for stone materials. There are numerous examples in California of small-scale workings where one or more men would gather what tool materials they needed for their own use. Only rarely were mineral deposits worked intensively on a large scale. In California, the major mines and quarries were the Glass Mountain, Sugar Hill, Borax Lake, Obsidian Butte, and St. Helena (localities 7, 8, 4, 15, 2, map 1) obsidian deposits; Santa Catalina Island steatite deposit (locality 1, map 2); and the San Bernardino County turquois mines. These may be compared to such localities as the Minnesota and Wisconsin catlinite quarries; Flint Ridge, Ohio; the extensive series of soapstone and quartzite quarries stretching along the Appalachian uplift; Los Cerillos, New Mexico; the Pennsylvania jasper quarries; the Missouri iron (hematite) mines; the mica mines of North Carolina and Alabama; and the salt mines of southern Nevada and Arizona. Some of the workings mentioned above were very large, and many of them were probably greater than any of the largest California quarries. For example, an estimated 100,000 cubic yards of material was removed from the Arkansas novaculite quarries at Magnet Cove. One flake heap at the obsidian quarries at Hidalgo, Mexico, was over 40 feet deep and comprised of 20,000 to 30,000 cubic feet of wastage. At the Clifton quarry in Fairfax County, Virginia, 10,000 cubic feet of soapstone was removed (Holmes, 1919, pp. 200, 218, 231).

A small number of specific techniques of rock extraction known in California were used elsewhere in North America, which suggests a common origin of these methods in the far distant past before the modern distribution of migrating Indian tribes was established. Alternative explanations for the presence of the same techniques among widely separated tribes are: (1) independent invention, or (2) a single origin with subsequent spread or diffusion of the idea beyond the boundaries

of the inventing tribe. The fire-quarrying method of the Wintu of the northern Sacramento Valley was also used in the Lake Superior copper mines, Wisconsin catlinite quarries, North Carolina mica mines, Pennsylvania jasper deposits, Arkansas novaculite (a variety of chert) quarries, New Mexican turquois mines, and the lode mines and obsidian quarries of Mexico.

Similar mining instruments were used everywhere—rough hand-picks, chisels, wedges, mauls, and hammers held in the hand or with a hafted wooden handle. The usual method of quarrying steatite by pecking out the bowl form in solid rock and then breaking it off by undercutting at the base was known in California at Santa Catalina Island and on the Klamath River (localities 1, 2, 3, map 3) and elsewhere at aboriginal quarries in Alabama, Rhode Island, District of Columbia, Virginia, and Massachusetts.

Short tunnels are reported in the San Bernardino County turquois mines, the New Almaden cinnabar mine, and for two flint outcrops (localities 1, 3, map 4) in California, and are reported elsewhere in North Carolina (mica), Missouri (hematite), Nevada and Arizona (salt), and in the Lake Superior region (copper).

There appears to be little or nothing that is distinctive per se of California mining and quarrying. The State was occupied by peoples of relatively simple culture, whose lithic tastes were correspondingly simple. Rocks and minerals which satisfied their unelaborate technological demands were universally used, and the local group made out largely with what resources its own territory contained. The New Almaden cinnabar pigment, Santa Catalina Island soapstone, and northern California obsidian flows were fairly intensively exploited and these materials were traded from tribe to tribe for considerable distances; a situation which suggests a parallel to the Wisconsin and Minnesota catlinite quarries which were visited by faraway tribes and whose product was traded for very long distances.

LITERATURE CITED

Anonymous

1939. Desert Indian well [at Torres]: Southwest Mus. Masterkey, vol. 13, p. 152. (Los Angeles.)

Abbott, C. C.

1879. [Objects of adornment and paint from archaeological sites at Santa Barbara]: U. S. Geog. Surveys W. 100th Mer. Rept., vol. 7, Archaeology, pp. 251-262.

Amsden, C.

1930. Homo Californianus: Southwest Mus. Masterkey, vol. 3, no. 6. (Los Angeles.)

Anderson, C. A.

1933. Volcanic history of Glass Mountain, northern California: Am. Jour. Sci., 5th ser., vol. 26, pp. 485 ff.

1936. Volcanic history of the Clear Lake area, California: Geol. Soc. America Bull., vol. 47, pp. 629-664.

de Angulo, J. and **Freeland, L. S.**

1929. Notes on the Northern Paiute of California: Jour. Soc. des Americanistes de Paris, n.s., vol. 21.

Baldwin, C. P.

1938. Toro Reservation Indian wells: Southwest Mus. Masterkey, vol. 12, pp. 151-153.

Ball, S. H.

1941. The mining of gems and ornamental stones by American Indians: Bur. Am. Ethnol., Bull. 128, Authrop. Paper 13.

Barrett, S. A.

1906. Indian opinions of the earthquake of 1906: Jour Am. Folklore, vol. 19, pp. 324-325.

1908. The ethnogeography of the Pomo and neighboring Indians: Univ. California Pub. Am. Arch. and Ethnol., vol. 6.

1933. Pomo myths: Public Mus. City of Milwaukee Bull., vol. 15.

Barrett, S. A. and **Gifford, E. W.**

1933. Miwok material culture: Public Mus. City of Milwaukee Bull., vol. 2, no. 4.

Barrows, D. P.

1900. The ethno-botany of the Coahuilla Indians of southern California. Chicago.

Bartlett, J. R.

1854. Personal narrative of explorations and incidents . . . connected with the United States and Mexican Boundary Commission, 1850-53. 2 vols. New York.

Bartlett, K.

1935. Prehistoric mining in the Southwest: Mus. Northern Arizona, Notes, vol. 7. (Flagstaff.)

Beals, R. L.

1933. Ethnology of the Nisenan: Univ. California Pub. Am. Arch. and Ethnol., vol. 31, no. 6.

Birch, F. and **Dennison, B.**

1938. The effect of pressure on the rigidity of rocks: Jour. Geol., vol. 46, no. 1.

Blake, W. P.

1899. Aboriginal turquoise mining in Arizona and New Mexico: Am. Antiquarian, vol. 21, no. 5.

Branner, G. C.

1927. Outlines of Arkansas' mineral resources. Arkansas Geol. Survey.

Browne, C. A.

1935. The chemical industries of the American aborigines: Isis, vol. 23, pp. 406-424.

Campbell, E. W. C. and **Campbell, W. H.**

1935. The Pinto Basin site: Southwest Mus. Papers, no. 9. (Los Angeles.)

Carter, G. F.

1941. Archaeological notes on a midden at Point Sal: Am. Antiquity, vol. 6, pp. 214-226.

Chesnut, V. K.

1902. Plants used by the Indians of Mendocino County, California: U.S. Nat. Herbarium, Contr., vol. 7, no. 3.

Dixon, R. B.

1905. The Northern Maidu: Am. Mus. Nat. History Bull., vol. 17, pt. 3.

Downer, S. A.

1854. The quicksilver mine of New Almaden: The Pioneer, vol. 2, pp. 220-228. (San Francisco.)

Drucker, P.

1941. Culture element distributions: XVII, Yuman-Piman: Univ. California Pub. Anthrop. Rec., vol. 6, no. 3.

Du Bois, C.

1908. Religion of the Luiseño Indians: Univ. California Pub. Am. Arch. and Ethnol., vol. 8, no. 3.

Dubois, C.

1935. Wintu ethnography: Univ. California Pub. Am. Arch. and Ethnol., vol. 36, no. 1.

Dubois, C. and **Demetracopoulou, D.**

1931. Wintu myths. Univ. California Pub. Am. Arch. and Ethnol., vol. 28, no. 5.

Dunn, H. H.

1930. Tracing the Pueblos to the Pacific: Touring Topics, vol. 22, pp. 48-50, 53.

Eisen, G.

1898. Long lost mines of precious gems are found again: San Francisco Call (newspaper), March 18, 1927.

Ellis, H. H.

1940. Flint working techniques of the American Indians. (Columbus, Ohio.)

Essene, F.

1942. Culture element distributions: XXI, Round Valley: Univ. California Pub., Anthrop. Rec., vol. 8, no. 1.

Farmer, M. F.

1937. An obsidian quarry near Coso Hot Springs: Southwest Mus., Masterkey, vol. 11, pp. 7-9.

Ford, H. C.

1887. Notes on excavations made in Indian burial places in Carpenteria: Santa Barbara Soc. Nat. History, Bull. 1, pp. 11-18.

Fowke, G.

1896. Stone art: Bur. Am. Ethnol., Ann. Rept. 13.

Gayton, A.

1929. Yokuts and Western Mono. Pottery-making: Univ. California Pub. Am. Arch. and Ethnol., vol. 24, no. 3.

Gibbs, G.

1860. Journal of the expedition of Redick McKee from Sonoma to the Klamath River in 1851. In H. R. Schoolcraft, Indian Tribes, vol. 3.

Gifford, E. W.

1923. Pomo lands on Clear Lake: Univ. California Pub. Am. Arch. and Ethnol., vol. 20, pp. 77-94.

1926. Clear Lake Pomo society. Univ. California Pub. Am. Arch. and Ethnol., vol. 18, no. 2.

1931. The Kamia of Imperial Valley: Bur. Am. Ethnol., Bull. 97.

1932. The Northfork Mono. Univ. California Pub. Am. Arch. and Ethnol., vol. 31, no. 2.

1933. The Cocopa: Univ. California Pub. Am. Arch. and Ethnol., vol. 31, no. 5.

Gifford, E. W. and **Kroeber, A. L.**

1937. Culture element distributions: IV, Pomo: Univ. California Pub. Am. Arch. and Ethnol., vol. 37, no. 4.

5—38463

Gifford, E. W. and Schenck, E. W.

1926. Archaeology of the southern San Joaquin Valley, Univ. California Pub. Am. Arch. and Ethnol., vol. 23, no. 1.

Goodman, M. E.

1944. The physical properties of stone tool materials: Am. Antiquity, vol. 4, pp. 415-433.

Gray, G. E.

1873. On the depression of the Colorado Basin: California Acad. Sci. Pr., vol. 4, pp. 228-230.

Hack, J. T.

1942. Prehistoric coal mining in the Jeddito Valley, Arizona: Harvard Univ., Peabody Mus. Papers, vol. 35, no. 2.

Harrington, J. P.

1928. Exploration of the Burton mound, Santa Barbara, California: Bur. Am. Ethnol., Ann. Rept. 44.

1932. Tobacco among the Karuk Indians of California: Bur. Am. Ethnol., Bull. 94.

Harrington, M. R.

1925. Ancient salt mine near St. Thomas, Nevada: Heye Foundation, Mus. Am. Indian, Indian Notes, vol. 2, pp. 227-231.

1926. Another ancient salt mine in Nevada: Heye Foundation, Mus. Am. Indian, Indian Notes, vol. 3, pp. 221-232.

Heizer, R. F.

1937. Baked-clay objects of the lower Sacramento Valley, California: Am. Antiquity, vol. 3, pp. 34-50.

1940. Aboriginal use of bitumen by the California Indians: California Div. Mines, Bull. 118, pt. 1, p. 74.

1941. Aboriginal trade between the Southwest and California. Southwest Mus. Masterkey, vol. 15, pp. 185-188.

1942. Walla Walla Indian expeditions to the Sacramento Valley, 1846-1848: California Hist. Soc. Quart., vol. 21, pp. 1-7.

Heizer, R. F. and Fenenga, F.

1939. Archaeological horizons in central California: Am. Anthropologist, vol. 41, pp. 378-399.

Hewes, G. W.

1941. Archaeological reconnaissance of the central San Joaquin Valley: Am. Antiquity, vol. 7, pp. 123-133.

Heye, G. G.

1921. Certain artifacts from San Miguel Island: Heye Foundation, Mus. Am. Indian, Indian Notes and Monographs, vol. 7, no. 4.

Hilton, J.

1936. The wells of the ancient Coahuillas: Westways, March.

Holmes, W. H.

1902. Anthropological studies in California: U. S. Nat. Mus., Ann. Rept. 1900, pp. 155-187.

1919. Handbook of aboriginal American antiquities: The lithic industries: Bur. Am. Ethnol., Bull. 30, pt. 1.

Hrdlicka, A.

1918. Recent discoveries attributed to early man in America: Bur. Am. Ethnol., Bull. 66.

Hudson, J. W.

1900. Preparation of acorn meal by Pomo Indians: Am. Anthrop., n.s., vol. 2, pp. 775-776.

Kelly, I. T.

1932. Ethnography of the Surprise Valley Paiute: Univ. California Pub. Am. Arch. and Ethnol., vol. 31, no. 3.

Kniffen, F. B.

1928. Achomawi geography: Univ. California Pub. Am. Arch. and Ethnol., vol. 23, no. 5.

Kroeber, A. L.

1906. [Indian beliefs concerning earthquakes]: Jour. Am. Folklore, vol. 19, pp. 322-323.

1908. Ethnography of the Cahuilla Indians: Univ. California Pub. Am. Arch. and Ethnol., vol. 8, no. 2.

1925. Handbook of the Indians of California: Bur. Am. Ethnol., Bull. 78.

1928. A Kato war: In, P. W. Schmidt Festschrift Volume.

1932. The Patwin and their neighbors: Univ. California Pub. Am. Arch. and Ethnol., vol. 29, no. 4.

1941. Culture element distributions: XV, salt, dogs, tobacco: Univ. California Pub., Anthrop. Rec., vol. 6, no. 1.

Kunz, G. F.

1898. Precious stones: U. S. Geol. Survey, Ann. Rept. 19, 1897-98, pt. VI, p. 504.

1899. Precious stones: U. S. Geol. Survey, Ann. Rept. 20, 1898-99, pt. VI, pp. 557-602.

1905. Precious stones, gems, jewelers' materials and ornamental stones of California: California Min. Bur., Bull. 37. Second ed.

Lillard, J. B., Heizer, R. F., and **Fenenga, F.**

1939. An introduction to the archeology of central California: Sacramento Junior College, Dept. Anthropology, Bull. 2.

Loeb, E. M.

1926. Pomo Folkways: Univ. California Pub. Am. Arch. and Ethnol., vol. 19, no. 2.

1932. The Western Kuksu cult: Univ. California Pub. Am. Arch. and Ethnol., vol. 33, no. 1.

Loud, L. L.

1918. Ethnology and archaeology of the Wiyot territory: Univ. California Pub. Am. Arch. and Ethnol., vol. 14, no. 3.

1924. The Stege mounds at Richmond, California: Univ. California Pub. Am. Arch. and Ethnol., vol. 17, no. 6.

Lord, J. K.

1866. The naturalist in Vancouver Island and British Columbia. London, 2 vols.

MacLeod, W. C.

1936. Conservation among primitive hunting peoples: Sci. Monthly, vol. 43, pp. 562-566.

Morris, E.

1928. An aboriginal salt mine at Campe Verde, Arizona: Am. Mus. Nat. History, Anthrop. Papers, vol. 30, pt. 3.

Pope, S. T.

1918. Yahi archery: Univ. California Pub. Am. Arch. and Ethnol., vol. 13, no. 3.

Powers, S.

1877. Tribes of California: Contr. North Am. Ethnol., vol. 3.

Randolph, G. C.

1935. Santa Catalina Island: The Mineralogist, vol. 3, no. 8, pp. 7-8.

Revere, J. W.

1849. A tour of duty in California. Boston.

Roberts, F. H. H., Jr.

1940. Developments in the problem of the North American Paleo-Indian: Smithsonian, Misc. Coll., vol. 100, pp. 51-116.

Rogers, D. B.

1929. Prehistoric man of the Santa Barbara coast. Santa Barbara.

Rogers, M. J.

1929 A. Report of an archaeological reconnaissance in the Mohave Sink region: San Diego Mus., Papers in Archaeology, vol. 1, no. 1.

1929 B. Stone art of the San Dieguito plateau: Am. Anthropologist, vol. 31, pp. 454-467.

1936. Yuman pottery making: San Diego Mus. Papers, no. 2.

Rust, H. N. and **Kroeber, A. L.**

1905. The obsidian blades of California: Am. Anthropologist, n.s., vol. 7, pp. 688-695.

Sapir, E.

1908. Luck stones among the Yana: Jour. Am. Folklore, vol. 21, p. 42.

Schenck, W. E.

1926. The Emeryville shellmound; final report: Univ. California Pub. Am. Arch. and Ethnol., vol. 23, no. 3.

Schenck, W. E. and **Dawson, E. J.**

1929. Archaeology of the northern San Joaquin Valley: Univ. California Pub. Am. Arch. and Ethnol., vol. 25, no. 4.

Schumacher, P.

1878. Ancient olla manufactory on Santa Catalina Island, Cal.: Am. Naturalist, vol. 12, p. 629.

1879. The method of manufacture of soapstone pots: U. S. Geog. Surveys W. 100th Mer. Rept., vol. VII, Archaeology, pp. 117-121. (Also published in Peabody Museum Reports, vol. 2, pp. 260-264, 1880.)

1880. The method of manufacturing pottery and baskets among the Indians of southern California: Harvard Univ., Peabody Mus., Ann. Rept. 12, vol. 11, no. 3.

Simpson, L. B.

1938. California in 1792: the expedition of José Longinos Martinez. (San Marino.)

Spier, L.

1923. Southern Diegueño customs: Univ. California Pub. Am. Arch. and Ethnol., vol. 20, pp. 297-360.

Sterrett, D. B.

1911. Gems and precious stones: Mineral Resources U. S., 1909, pt. 2, pp. 739-808.

Steward, J. H.

1933. Ethnography of the Owens Valley Paiute: Univ. California Pub. Am. Arch. and Ethnol., vol. 33, no. 3.

1938. Basin-Plateau aboriginal socio-political groups: Bur. Am. Ethnol., Bull. 120.

Stewart, O. C.

1943. Notes on Pomo ethnogeography: Univ. California Pub. Am. Arch. and Ethnol., vol. 40, no. 2.

Strong, W. D.

1929. Aboriginal society in southern California: Univ. California Pub. Am. Arch. and Ethnol., vol. 26.

Swan, J. G.

1857. Northwest coast; or, three years' residence in Washington Territory. (New York.)

Taylor, A. S.

1860. San Joaquin Indians, No. 2. California Farmer (newspaper). Dec. 7.

1861. The Indianology of California. California Farmer (newspaper). June 7.

1864. Santa Cruz County Indians. In California Farmer (newspaper), p. 58.

Treganza, A. E.

1942. Archaeological reconnaissance of southeastern California and northeastern Baja California: Am. Antiquity, vol. 8, pp. 152-163.

Treganza, A. E., Smith, C. E., and **Weymouth, W. D.**

N. D. Archaeological survey of Round Valley and adjacent drainage. (MS.)

Voegelin, E. W.

1942. Culture element distributions: XX, northeast California: Univ. California Pub., Anthrop. Rec., vol. 7, no. 2.

Wagner, H. R.

1929. Spanish voyages to the northwest coast: California Hist. Soc., Special Pub. no. 4. (San Francisco.)

Walker, E. F.

1935. A prehistoric soapstone quarry: Southwest Mus. Masterkey, vol. 6, pp. 178-180.

1936. Obsidian used by prehistoric Californians: Southwest Mus. Masterkey, vol. 10, p. 15.

1938. Desert Indian wells: Southwest Mus. Masterkey, vol. 12, pp. 110-112.

Waring, G. A.

1915. Springs of California: U. S. Geol. Survey Water-Supply Paper 338.

Waterman, T. T.

1910. Religious practices of the Diegueño Indians: Univ. California Pub. Am. Arch. and Ethnol., vol. 8, no. 6.

Wedel, W. R.

1941. Archaeological investigations at Buena Vista Lake, Kern Co., California: Bur. Am. Ethnol., Bull. 130.

Woodward, A.

1937. Atlatl dart foreshafts from the La Brea pits: Southern California Acad. Sci. Bulletin, vol. 36, pp. 41-60.

Yarrow, H. C.

1879. Report on the operations of a special party for making ethnological researches in the vicinity of Santa Barbara: U. S. Geog. Surveys W. 100th Mer. Rept., vol. 7, Archaeology, pp. 32-47.

SELECTED BIBLIOGRAPHY OF NORTH AMERICAN INDIAN MINING AND QUARRYING

The most important papers on North American Indian mining and quarrying have been cited in topical order as follows: General treatises on American Indian mining and quarrying; soapstone (steatite); turquois; flint and chert; quartzite; jasper; obsidian; catlinite; hematite; coal; salt; mica; jade; galena; copper; miscellaneous (argillite, gems); stone-working processes; metallurgy.

General

Ball, S. M.

1931. Historical notes on gem mining: Econ. Geology, vol. 26, pp. 681-738.

Bartlett, K.

1935. Prehistoric mining in the Southwest: Mus. Northern Arizona, Notes, vol. 7. (Flagstaff.)

Hendrichs, P. R.

1940-41. Datos sobre la tecnica minera prehispánica. El Mexico Antiguo, vol. 5, pp. 148-160; vol. 6, pp. 179-194. (Mexico.)

Holmes, W. H.

1907. Mines and quarries [of the American Indians]: Bur. Am. Ethnol. Bull. 30, pt. 1, pp. 864-867. (Washington.)

1919. Handbook of aboriginal American antiquities. Part 1, The lithic industries: Bur. Am. Ethnol., Bull. 60. (Washington.)
a. Quartzite boulder quarries, District of Columbia, pp. 159-172.
b. Flint quarries at Flint Ridge and Warsaw, Ohio, pp. 173-184.
c. Flint quarries in West Virginia, Kentucky, and Indiana, pp. 185-186.
d. Flint quarries at Mill Creek, Illinois, pp. 187-194.
e. Flint quarry near Crescent, Missouri, p. 195.
f. Novaculite quarries in Arkansas, pp. 196-200.
g. Chert quarries of Oklahoma and Kansas, pp. 201-209.
h. Quartzite quarries in Wyoming, pp. 210-213.
i. Steatite quarries in District of Columbia, California, Virginia, Guatemala, pp. 228-240.
j. Mica mines of the south Appalachian region, pp. 241-252.
k. Catlinite quarries in Minnesota, pp. 253-265.
l. Hematite ore and paint mine, Missouri, pp. 266-270.
m. Turquoise mines of New Mexico, pp. 271-273.

Lincoln, F. C.

1924. Ancient mining: Black Hills Engineer, vol. 12, no. 1. (Rapid City, North Dakota.)

Packard, P. L.

1893. Pre-Columbian mining in North America. Am. Antiq. and Orient. Jour., vol. 15, pp. 152-164. (Chicago.)

Soapstone (Steatite)

Barber, E. A.

1878. [Notes on a steatite quarry near Providence, Rhode Island]: Am. Naturalist, vol. 12, pp. 403-404.

Bullen, R. P.

1940. The Dolly Bond steatite quarry: Massachusetts Arch. Soc. Bull., vol. 2, no. 1. (Andover.)

Bushnell, D. K.

1926. Ancient soapstone quarry in Albemarle County, Virginia: Jour. Washington Acad. Sci., vol. 16, no. 19.

Chase, H. E.

1885. Notes on the Wampanoag Indians: Smithsonian Inst. Ann. Rept. 1883, pp. 878-907 (pp. 900-901, Rhode Island soapstone quarries).

Cushing, F. H.

1878. [Notes on a soapstone quarry in Amelia County, Virginia]: Am. Naturalist, vol. 12, pp. 630-631.

Fowler, W. S.

1943. Soapstone bowl making as practiced at the Westfield quarry: Massachusetts Arch. Soc. Bull., vol. 4, pp. 42-44. (Boston.)

Holmes, W. H.

1890. Excavations in an ancient soapstone quarry in the District of Columbia: Am. Anthropologist, o.s., vol. 3, pp. 321-330.

1897. Stone implements of the Potomac-Chesapeake tidewater province: Bur. Am. Ethnol., Ann. Rept. 15 (pp. 106-133, quarries of District of Columbia, Virginia, and Maryland).

Kengla, L. A.

1883. Archaeology of the District of Columbia. Washington.

McGuire, J. D.

1883. Aboriginal quarries—soapstone bowls and the tools used in their manufacture: Am. Naturalist, vol. 17, pp. 587-595.

1882. Soapstone quarries and aboriginal tools for working soapstone. Anthrop. Soc. Washington, vol. 2, p. 39 (quarries and tools of Maryland and the District of Columbia).

Mohr, C.

1882. Aboriginal soapstone quarry and shell-heaps in Alabama: Smithsonian Inst. Ann. Rept. 1881, pp. 617-619.

Putnam, F. W.

1880. The manufacture of soapstone pots by the Indians of New England: Harvard Univ., Peabody Mus. Rept., vol. 2, pp. 273-276.

Reynolds, E. R.

1880. Aboriginal soapstone quarries in the District of Columbia: Harvard Univ., Peabody Mus. Rept., vol. 2, pp. 526-535.

Skinner, A.

1908. A Massachusetts soapstone quarry: Am. Anthropologist, n.s., vol. 10, pp. 702-703.

Walker, J. W.

1887. [Soapstone quarry in Georgia]: Science, o.s., vol. 9, p. 10.

Turquois

Blake, W. P.

1858. The chalchihuite of the ancient Mexicans; its locality and association and its identity with turquoise: Am. Jour. Sci., 2d ser., vol. 25, pp. 227-232.

1883. New locality of the green turquoise known as chalchihuite: Am. Jour. Sci., 3d ser., vol. 25, pp. 197-200.

1899. Aboriginal turquoise mining in Arizona and New Mexico: Am. Antiquarian, vol. 21, no. 5. (Chicago.)

Johnson, D. W.

1903. The geology of the Cerillos Hills, New Mexico: New Mexico School of Mines Quart., vol. 24, no. 4 (pp. 493-499, Los Cerillos turquois mines).

Kunz, G. F.

1890. Gems and precious stones of North America. New York. (pp. 54-59, Indian mining of turquois.)

Nuttall, Z.

1901. Chalchihuite [turquoise] in ancient Mexico: Am. Anthropologist, n.s., vol. 3, pp. 227-238. (Menasha.)

Pogue, J. E.

1912. The aboriginal use of turquois in North America: Am. Anthropologist, vol. 14, pp. 437-466. (Menasha.)

1915. The turquoise: Nat. Acad. Sci. Mem. 3, vol. 12. (Washington.)

Saville, M.

1922. Turquoise mosaic art in ancient Mexico. (New York.)

Silliman, B.

1881. Turquoise in New Mexico: Am. Jour. Sci., 3d ser., vol. 22, pp. 67-71.

Flint

Fowke, G.

1928. Archaeological investigations—II. Bur. Am. Ethnol., Ann. Rept. 44, pp. 401-540 (pp. 505-540, aboriginal quarries in Ohio, West Virginia, Kentucky, Tennessee, Indiana, Illinois, and Missouri).

Holmes, W. H.

1894. An ancient Indian quarry in Indian Territory: Bur. Am. Ethnol., Bull. 21. (Washington.)

1897. Stone implements of the Potomac-Chesapeake tidewater province: Bur. Am. Ethnol., Ann. Rept. 15 (pp. 77-78, Virginia flint quarries).

Hovey, H. C.

1880. On the alabaster quarries, flint mines, and other antiquities of Wyandot Cave [Kentucky]: Am. Assoc. for Advancement of Sci., Proceedings, vol. 29, pp. 725-731.

Phillips, W. A.

1900. Aboriginal [flint] quarries and shops at Mill Creek, Illinois: Am. Anthropologist, n.s., vol. 2, pp. 37-52. (Menasha.)

Smith, C. M.

1885. A descriptive sketch of Flint Ridge, Licking Co., Ohio: Smithsonian Inst., Ann. Rept. 1884, pp. 851-873. See also "Mica," item 2 (pp. 618-628).

Novaculite

Holmes, W. H.

1891. Aboriginal novaculite quarries in Garland Co., Kansas: Am. Anthropologist, o.s., vol. 4, pp. 313-316.

Jenney, W. P.

1891. Ancient novaculite mines near Magnet Cove, Hot Springs County, Arkansas: Am. Anthropologist, o.s., vol. 4, pp. 316-318.

Lemley, H. J.

1942. Prehistoric novaculite quarries of Arkansas: Texas Archaeology and Paleo. Soc. Bull., vol. 14, pp. 32-37. (Abilene.)

Quartzite

Dorsey, J. O.

1900. An aboriginal quartzite quarry in eastern Wyoming: Field Columbian Mus., Anthrop. Ser., vol. 2, no. 4. (Chicago.)

Holmes, W. H.

1890. A quarry workshop of the flaked-stone implement makers of the District of Columbia: Am. Anthropologist, o.s., vol. 3, pp. 1-26.

1892. On the so-called paleolithic implements of the upper Mississippi: Am. Assoc. for Advancement of Sci., Proceedings, vol. 41, pp. 280-281 (quarry at Little Falls, Minn.).

1894. Stone implements of the Potomac-Chesapeake tidewater province: Bur. Am. Ethnol., Ann. Rept. 15.

Knight, W. C.

1898. Prehistoric quartzite quarries in central eastern Wyoming: Science, n.s., vol. 7, pp. 308-311.

Jasper

Deisher, H.

1932. South Mountain Indian [jasper] quarries: Bucks County, Pennsylvania Hist. Soc., Coll. of Papers, vol. 6, pp. 334-341.

Mercer, H. C.

1893. Another ancient source of jasper blade material east of the middle Alleghanies: Am. Assoc. for Advancement of Sci., Proc. vol. 42, pp. 307-308 (sites in southeast New Jersey and Dorchester County, Maryland).

1894. Indian jasper mines in the Lehigh Hills [Pennsylvania]: Am. Anthropologist, o.s., vol. 7, pp. 80-92.

1895. Jasper and stalagmite quarried by Indians in the Wyandotte Cave [Indiana]: Am. Philos. Soc. Proceedings, vol. 34, pp. 396-400. (Philadelphia.)

Obsidian

Breton, A.

1905. Some obsidian workings in Mexico: Internat. Cong. Americanists, Proceedings 13th sess., New York, 1902, pp. 265-268. (New York.)

Brower, J. V.

1897. The Missouri River and its utmost source. St. Paul. (Pp. 20-24, Yellowstone obsidian cliffs.)

Holmes, W. H.

1879. Notes on an extensive deposit of obsidian in Yellowstone National Park: Am. Naturalist, vol. 13, pp. 247-250. (Philadelphia.)

1900. The obsidian mines of Hidalgo, Mexico: Am. Anthropologist, n.s., vol. 2, pp. 405-416. (Menasha.)

Lowenstern, I.

1843. La Mexique. Paris. (Pp. 244-245, obsidian quarries of Mexico.)

Randolph, G. C.

1935. Gem-like obsidian of Glass Buttes, Oregon: The Mineralogist, vol. 3, pp. 11-12, 26-27.

Catlinite

Brown, C. E.

1914. A Wisconsin catlinite quarry: Wisconsin Archaeologist, vol. 13, pp. 80-82. (Milwaukee.)

Hayden, F. V.

1866. On the pipestone quarry of Dakota: Philadelphia Academy Nat. Sci., Proceedings.

Holmes, W. H.

1892. Sacred pipestone quarries of Minnesota and ancient copper mines of Lake Superior: Am. Assoc. for Advancement of Sci., Proceedings, vol. 41, pp. 277-279.

West, G. A.

1910. Pipestone quarries of Barron Co., Wisconsin: Wisconsin Archaeologist, vol. 10, pp. 5-64. (Milwaukee.)

1934. Tobacco, pipes, and smoking customs of the American Indians: Milwaukee Public Mus., Bull., vol. 17, pt. 1. (Pp. 329-331, catlinite quarries in Minnesota and Wisconsin.)

White, C. A.

1869. A trip to the great red pipestone quarry of Minnesota: Am. Naturalist, vol. 2, pp. 644-653.

Hematite

Bushnell, D. I.

1903. Discovery of a prehistoric hematite quarry: Records of the Past, vol. 2, p. 154. (Hematite ore and ocher mine in Franklin County, Missouri.)

Holmes, W. H.

1904. Traces of aboriginal operations in an iron mine near Leslie, Missouri: Smithsonian Inst., Ann. Rept. 1903, pp. 723-726.

Moorehead, W. K.

1912. Hematite implements of the United States: Phillips Acad., Dept. Archaeology, Bull. 6. (Andover, Massachusetts.)

Reynolds, E. R.

1881. Aboriginal paint quarry (abstract): Anthrop. Soc. Washington Trans., 1880 and 1881, pp. 11-12. (Hematite quarry in Maryland.)

Spier, L.

1928. Havasupai ethnography: Am. Mus. Nat. History, Anthrop. Papers, vol. 29, pt. 3. New York. (Pp. 196-197, hematite mine in Arizona.)

Coal

Brew, J. O. and Hack, J. T.

1939. The prehistoric use of coal by Indians of northern Arizona: Mus. Northern Arizona, Plateau, vol. 12, no. 1. (Flagstaff.)

Colton, H. S.

1936. [Ancient] Hopi coal mines: Mus. Northern Arizona, Notes, vol. 8, no. 12. (Flagstaff.)

Hack, J. T.

1942. Prehistoric coal mining in the Jeddito Valley, Arizona: Harvard Univ., Peabody Mus. Papers, vol. 35, no. 2.

Hough, W. T.

1927. First use of coal: El Palacio, vol. 22. (Santa Fe, New Mexico.)

Salt

Harrington, M. R.

1925. Ancient salt mine near St. Thomas, Nevada: Heye Foundation, Mus. Am. Indian, Indian Notes, vol. 2, pp. 227-236. (New York.)

1926. Another ancient salt mine in [southern] Nevada: Heye Foundation, Mus. Am. Indian, Indian Notes, vol. 3, pp. 221-232. (New York.)

Hill, W. W.

1940. Navajo salt gathering: Univ. New Mexico Anthrop. Ser. Bull., vol. 3, no. 4. (Albuquerque.) (Salt gathering from saline lakes.)

Morris, E. H.

1928. An aboriginal salt mine at Camp Verde, Arizona: Am. Mus. Nat. History, Anthrop. Papers, vol. 30, pt. 3. (New York.)

Mica

Fontaine, W. F.

1883. Notes on the occurrence of certain minerals in Amelia County, Virginia: Am. Jour. Sci., 3d ser., vol. 25, pp. 330-339.

Fowke, G.

1902. The archaeological history of Ohio. (Columbus.) (Pp. 701-704, North Carolina Indian mica mines.)

Gesner, W.

1890. Mica beds in Alabama: Smithsonian Inst., Ann. Rept. 1879, p. 382.

Smith, C. D.

1877. Ancient mica mines in North Carolina: Smithsonian Inst., Ann. Rept. 1876, pp. 441-443.

Jade

Dawson, G. M.

1887. Note on the occurrence of jade in British Columbia and its employment by the natives: Canadian Rec. Sci., vol. 2, no. 6.

Emmons, G. T.

1923. Jade in British Columbia and Alaska and its use by the natives: Heye Foundation, Indian Notes and Monographs, no. 35. (New York.)

Gann, T.

1925. Maya jades: Internat. Cong. Americanists, Proceedings 21st session, Gökborg, 1924, pt. 2, pp. 274-282. (Gökborg.)

Stoney, G. M.

1900. Naval explorations in Alaska: U. S. Naval Inst., Annapolis, Md. (Pp. 56-57, jade mine on Kobuk River.)

Galena

Chapin, F. H.

1892. The land of the Cliff Dwellers. Boston. (P. 30, New Mexico Indian galena mine.)

Newberry, J. S.

1892. The ancient civilizations of America: Popular Sci. Monthly, vol. 41, pp. 187-200. (P. 191, galena mine in Kentucky.)

Copper

Anonymous

1897. Aboriginal copper mines in Minnesota: Am. Anthropologist, o.s., vol. 10, p. 91. (Menasha.)

Barrett, S. A.

1924. Aboriginal copper mines at McCargoe's Cove, Isle Royale: Milwaukee Public Mus., Yearbook, vol. 4.

Brown, C. E.

1904. The native copper implements of Wisconsin: Wisconsin Archaeologist, vol. 3, pp. 49-84.

Fox, G. R.

1911. The ancient copper workings on Isle Royale: Wisconsin Archaeologist, vol. 10, pp. 76-100.

Holmes, W. H.

1901. Aboriginal copper mines of Isle Royale, Lake Superior: Am. Anthropologist, n.s., vol. 3, pp. 684-696. (Menasha.)

Houghton, J. J.

1879. Ancient copper mines of Lake Superior: Wisconsin Hist. Coll., vol. 8, pp. 140-151. (Madison.)

Packard, R. L.

1893. Pre-Columbian copper mining in North America: Smithsonian Inst., Ann. Rept. 1892, pp. 175-198. (Washington.)

Phillips, G. B.

1923. A prehistoric copper mine: Wisconsin Archaeologist, n.s., vol. 2, pp. 151-154. (Milwaukee.)

West, G. A.

1929. Copper: its mining and use by the aborigines of the Lake Superior region: Milwaukee Public Mus. Bull., vol. 10, pp. 1-184.

Whittlesey, C.

1863. Ancient copper mining on shores of Lake Superior: Smithsonian Inst., Contr. to Knowledge, vol. 13, article 4. See also "Catlinite," item 3 and "Mica," item 2 (pp. 704-728).

Miscellaneous

Ball, S. H.

1931. Historical notes on gem mining: Econ. Geology, vol. 26, pp. 681-738.

Bartlett, K.

1939. A prehistoric "mine" of red argillite, resembling pipestone near Del Rio, Arizona: Mus. Northern Arizona, Mus. Notes, vol. 11, pp. 75-78.

Harrington, M. R.

1924. A West Indian gem center: Heye Foundation, Mus. Am. Indian, Indian Notes, vol. 1, no. 4, pp. 184-189.

Mercer, H. C.

1893. The result of excavations at the ancient argillite quarries, recently discovered near the Delaware River on Gaddis Run: Am. Assoc. for Advancement of Sci., Proceedings, vol. 42, pp. 304-307.

Nininger, H. H.

1938. Meteorite collecting among ancient Americans: Am. Antiquity, vol. 4, pp. 39-40.

For alabaster (stalagmite) quarrying, see "Jasper," item 4 and "Flint," item 4. For meteoric iron see "Metallurgy," item 1.

Stone-Working Processes

Holmes, W. H.

1895. Archaeological studies among the ancient cities of Mexico: Field Mus. Nat. History, Anthrop. Ser., vol. 1, no. 1. (Chicago.) (Pp. 279-287, quarrying and cutting stone at Mitla.)

1902. Order of development of the primal stone shaping arts: Smithsonian Inst., Ann. Rept. 1901.

1919. Handbook of aboriginal American antiquities. Part 1, The lithic industries: Bur. Am. Ethnology, Bull. 60. (Pp. 278 ff., "The stone-shaping arts"; pp. 274-277, quarries of building stone in Central and South America.)

McGuire, J. D.

1892. Materials, apparatus, and processes of the aboriginal lapidary: Am. Anthropology, o.s., vol. 5, pp. 165-176.

1896. Study of the primitive methods of drilling: U. S. Nat. Mus., Ann. Rept. 1894.

Nelson, N. C.

1916. Flint working by Ishi. W. H. Holmes Anniversary Volume, pp. 397-402. (Washington.)

Rau, C.

1869. Aboriginal stone drilling: Smithsonian Inst., Ann. Rept. 1868, pp. 392-400.

Sellers, G. E.

1886. Observations on stone chipping: Smithsonian Inst., Ann. Rept. 1885, pt. 1, pp. 871-891.

Wilson, C. L. and Sayre, M.

1935. A brief metallographic study of primitive copper work: Am. Antiquity, vol. 1, pp. 109-112.

Metallurgy

Brown, C. E.

1904. The native copper ornaments of Wisconsin: Wisconsin Archaeologist, vol. 3, pp. 101-121.

Cushing, F. H.

1894. Primitive copper working: an experimental study: Am. Anthropology, o.s., vol. 7, pp. 93-117.

Farabee, W. C.

1921. The use of metals in prehistoric America: Univ. Pennsylvania, Mus. Jour., March.

Handbook of American Indians

1910, 1912. Bureau of American Ethnology, Bull. 30, Parts 1 and 2.
Gold, Part 1, pp. 495-496.
Copper, Part 1, pp. 343-347.
Silver, Part 2, p. 573.
Iron (meteoric), Part 1, p. 615.
Metal working in general, Part 1, pp. 847-849.

Houck, L.

1882. On the mound builder's knowledge of metals: Kansas City Rev. of Sci. and Ind. for 1882.

Peet, S. D.

1906. Copper relics among the mounds: Am. Antiquarian, vol. 28, pp. 213-228.

1906. The copper age in America: Am. Antiquarian, vol. 28, pp. 149-164.

Putnam, F. W.

1882. Notes on the copper objects from North and South America, contained in the collections of the Peabody Museum: Harvard Univ., Peabody Mus., Ann. Rept. of Trustees, vol. 15, no. 2, pp. 83-148.

Rickard, T. A.

1932. Man and metals. New York. 2 vols.

1934. The use of native copper by the indigines of North America: Royal Anthrop. Inst. Jour., vol. 64, pp. 265-287. (London.)

MINERAL EXHIBIT AND STATISTICS

FLUORESCENT MINERALS IN THE EXHIBIT OF THE STATE DIVISION OF MINES

By Henry H. Symons*

Of the 10,000 specimens in the main mineral exhibit of the Division of Mines, Ferry Building, San Francisco, about half have been examined under ultra-violet lights, and more than 250 have been found to fluoresce. These specimens when brought under a ray of invisible ultra-violet or 'black light' were found to emit visible light of one color or another. This work has been carried on at night by members of the staff from time to time since 1930. Recently the principal commercial use of this property has been the detection of scheelite,[1] an ore of tungsten, for war purposes. Scheelite fluoresces bluish white. An older commercial use of the property was detection of the zinc mineral willemite at Franklin Furnace, New Jersey. Willemite fluoresces a brilliant green. In the number of minerals that are counted as fluorescent are specimens of the same mineral from different localities but no duplicates from the same locality. Calcite from one locality fluoresces red, from a second locality pink, from a third locality pale blue, from a fourth locality yellow, from a fifth locality green, and from a sixth locality cream. From a seventh locality the calcite is found to exhibit blue phosphorescence, that is, the emission of visible light persists for a short time after the ultra-violet ray is turned off. The different colors are the result of different impurities in the calcite. This is discussed further in the accompanying article, *Fluorescent Minerals Used in Lighting and Elsewhere.* Scheelite seems to be an exception to the rule that fluorescence is caused by impurities. Of thousands of specimens examined by the Division of Mines, all have been found to fluoresce. However, molybdenum in the scheelite changes the color of the emitted light from bluish white to yellow. Small amounts of molybdenum give just enough yellow to neutralize the blue, and the result is fluorescent light that is nearly pure white. To those readers who wish a theoretical explanation of the phenomenon of fluorescence, the recent book by Pringsheim and Vogel [2] on luminescence is recommended.

The first ultra-violet light used by the Division of Mines was a single argon bulb. Very few minerals would fluoresce under this light. Later a bank of six argon bulbs gave fairly good results in a dark room. An iron spark was used to detect scheelite. This light results from a high voltage discharge between two iron electrodes.[3] The amount of ultra-violet light produced from a given input of power is very small compared to the amount produced by the modern cold quartz tube such as is used in the Mineralight. Other lights tried were: R. & M. light without filter; carbon arc with filter; several models of Mineralight; Chesbert light; NiCo tubes, both 50-inch and 22-inch; General Electric HG 4 light;

---

* Statistician and Curator, California State Division of Mines.

[1] Heizer, Ott F., Use of ultra-violet light in prospecting for scheelite: California Div. Mines Rept. 34, pp. 331-333, 1938.

[2] Pringsheim, Peter, and Vogel, Marcel, Luminescence of liquids and solids and its practical applications, 201 pp., Interscience Publishers, Inc., New York, N. Y., 1943.

[3] Vanderburg, W. O., A note on the use of ultraviolet lamps in mines for rapid detection of scheelite in ores by fluorescence: U. S. Bur. Mines Inf. Circ. 6873, pp. 1-3, 1935.

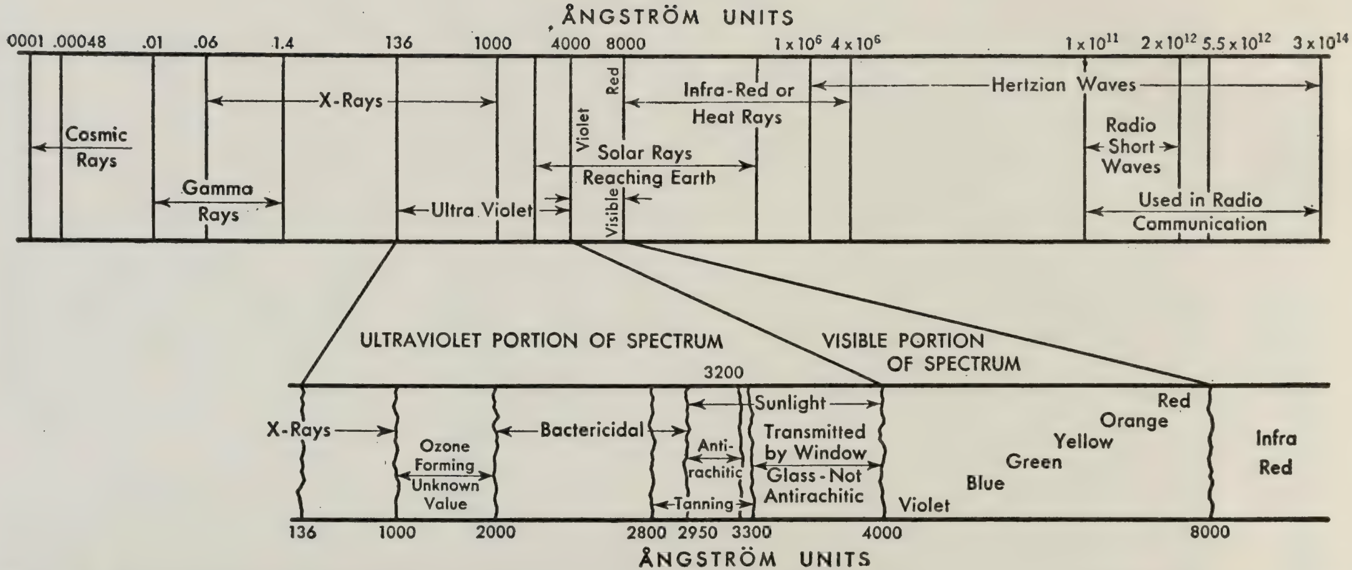


FIG 1. One Ångström unit, used to express the wave length of light and ultra-violet radiations, is equal to 1/10,000,000th of a millimeter, or approximately 1/250,000,000th of an inch. *Reprinted from "The Rentschler-James Process," by Westinghouse Electric and Manufacturing Company.*

photoflood light in red-purple envelope. All of the lights mentioned were not available at one time; hence it has not been possible to compare results from all of them. However, many minerals that did not fluoresce under the older ultra-violet lamps do fluoresce under recently improved models. An example of this is a scheelite crystal which showed no fluoresence under the iron spark or an early type of cold quartz tube without filter, but which showed strong fluorescence under a late model of cold quartz tube with filter. The filter cuts off visible rays with the exception of a little purple light, and this makes the fluorescence more prominent.

The wave-length of light is measured in the Ångström unit, abbreviated A.U., which is simply a very small unit of length. An inch contains 254,001,000 A.U. The following table shows the relations between the inch and several metric units including the Ångström unit:

1 meter =	39.37	inches
1 millimeter =	0.03937	"
1 micron =	0.00003937	"
1 A.U. =	0.000000003937	"

Visible light has a range in wave-length from 4000 A.U. for violet to 8000 A.U. for red. This is a very narrow range in the known series of similar waves. Radio waves in the broadcasting band have wave-lengths of hundreds of meters. X-rays have wave-lengths of 1000 A.U. to 0.06 A.U. Waves only slightly shorter than 4000 A.U. are called near ultra-violet, and such waves occurring in sunlight cause sun-tan of the skin. Many minerals fluoresce when exposed to ultra-violet of this kind, but some minerals fluoresce only when exposed to shorter waves. Scheelite fluoresces under ultra-violet of a wave-length of about 2500 A.U., and this is shorter than any wave found in sunlight. At the boundary between visible and invisible violet (4000 A.U.) there are 63,500 light-waves in a single inch.

As the iron spark produces only a small amount of ultra-violet light and considerable white light, and as the use of a filter is not practicable, this light gives good results only with specimens having a strong tendency to fluoresce. Its light contains some ultra-violet of a wave-length of 2500 A.U.; hence it was useful in detecting scheelite before the cold quartz type of light was developed. Cold quartz lights, including the Mineralight, Chesbert light and others, equipped with special Corning glass filters, produce ultra-violet light of wave-lengths ranging from 2500 A.U. to 4000 A.U. They are most useful in examining minerals that fluoresce under the influence of the lower wave-lengths around 2500 A.U., such as scheelite. Carbon arcs produced by carbons to which salts have been added are supposed to yield ultra-violet light of wave-lengths as low as 1700 A.U. However, filters must be used to remove white light and the filters do not transmit light of smaller wave-length than about 2500 A.U.; hence no advantage is gained. Lights such as G.E. NiCo, G.E. HG4, argon bulbs, and photo-flood light in red-purple envelope or with filter do not allow ultra-violet light of shorter wave length than about 3000 A.U. to pass through their envelopes even if special glasses are used. More minerals fluoresce under this wave-length (3000 to 4000 A.U.) than under shorter wave-lengths, but the commercial minerals, scheelite and zircon, fluoresce only under the shorter wave-length (about 2500 A.U.). Both the willemite and the calcite from Franklin Furnace, New Jersey, fluoresce better under the short wave-length (2500 A.U.) than under the longer wave-lengths (3000 to 4000 A.U.).

Case and specimen No.[1]	Mineral[2]	Location[3]	Color[4]	Wave length[5]	Notes
145-20380	Autunite, $CaO.2UO_3.$-$P_2O_5.8H_2O$	Indo China	Yellowish green	nuv	Probably the most brilliant fluorescence of any specimen in collection. Other specimens from many locations give good fluorescence in same color.
119-6492	Brucite, $MgO.H_2O$	Texas	Blue white	nuv	Other brucite from Nevada fluoresced same color but not so brilliantly.
133-12742	Calcite, $CaCO_3$	Franklin, N. J.	Red	uv	This mineral gives a good red fluorescence with the shorter wave lengths. It has been observed that calcite when a gangue mineral of metallic ores usually fluoresces. The color of the fluorescent light seems to be independent of kind of metal seen in the ore.
120-5009	Calcite, $CaCO_3$	Klamath River, Siskiyou County, California	Yellow	nuv	Many calcites from numerous locations fluoresce in different intensities of green, blue, yellow, pink and red. Some specimens show phosphorescence.
617-18857	Californite (vesuvianite)	Pulga, Butte County, California	Golden	nuv	Other specimens from different localities fluoresce with other colors.
616-18820	Chalcedony, SiO_2	Near Barstow, San Bernardino County, California	Blue green	nuv	This specimen as well as many other chalcedony specimens shows fair fluorescence in colors from pale blue to pale green.
115-15833	Chrysoprase (chalcedony)	9½ miles east of Porterville, Tulare County, California	Blue-green	--------	Gem-quality.

806[6]-20813	Curtisite, $C_{24}H_{18}$	Skaggs Springs, Sonoma County, California	Yellowish green	nuv	The most brilliant fluorescence of all California minerals examined.
A806	Dolomite $(Ca.Mg)CO_3$, gangue in quicksilver ore	Mirabel Mine, near Middletown, Lake County	Bands of blue, green and yellow	nuv	Many good specimens have been found on waste dump. The whole specimen does not fluoresce but individual bands do in several colors. Samples from other quicksilver mines fluoresce equally well.
113-20513	Fluorite, CaF_2	Cumberland, England	Lavender	nuv	One of the very brilliant fluorescent minerals. Some California fluorite from near Barstow, San Bernardino County, fluoresces the same color but not so brightly.
113-20847	Fluorite CaF_2	Clay Center, Ohio	Yellow brown	nuv	The only mineral in our collection fluorescing a brown color.
617-18843	Fossil *Equisetum* (chalcedony)	Lower end of Mojave Desert, San Bernardino County, California	Golden	nuv	An unusual specimen. Fossils containing calcite or chalcedony are likely to fluoresce.
616-20649	Garnet (almandite variety)	Alder Gulch, Montana	Red	nuv	Almandite garnets often give good red fluorescence.
148-20889	Gypsum crystals, $CaSO_4.2H_2O$	Santa Monica Cliffs, Los Angeles County, California	Green	nuv	This sample fluoresces weakly but phosphoresces fairly well. Gypsum taken from other places along the coast reacts similarly.
703-19002	Kunzite (spodumene) $LiAl(SiO_3)_2$	Pala, San Diego County, California	Orange brown	nuv	Other specimens from same locality fluoresce yellowish green.
617-18857	Lapis-lazuli (lazurite) $3NaAlSiO_4.Na_2S$	Near Upland, San Bernardino County, California	Red	nuv	This specimen and also Indian lapis lazuli fluoresce a brilliant red.

Case and specimen No.[1]	Mineral[2]	Location[3]	Color[4]	Wave length[5]	Notes
115 and 806-20784	Moss opal	Virgin Valley, Nevada	Deep green	uv	Differs from the regular Virgin Valley opal in that it takes a shorter wave length to excite fluorescence and the color of the light is a much more vivid green.
616 and 806-20699	Onyx (chalcedony) SiO_2	Manhattan n ine, Knoxville, Napa County, California	Bands of blue and yellow	nuv	Some bands fluoresce blue, others yellow and others show no fluorescence.
115-20784	Opal, $SiO_2.nH_2O$	Virgin Valley, Nevada	Yellowish green	nuv	Good fluorescence even with argon light. Opals from several other locations fluoresce a similar color but not so brightly.
617-18873	Petrified palm root (chalcedony)	Near Randsburg, Kern County, California	Golden	nuv	The milky chalcedony in many petrified materials gives beautiful fluorescent designs.
806	Petroleum	Sec. 24, T. 21 S., R. 16 E., M.D. Kettleman North Dome oil field, Fresno County, California. Depth, 10,927 feet	Green yellow	nuv	Petroleum fluoresces from light at the lower end of the visible spectrum. Numerous samples from many oil fields have been tried and all fluoresce. The fluorescence of the heavier crudes tends towards green and that of the lighter to blue. Most petroleum products from refineries fluoresce also. Gasoline, white medicinal oil, and paraffine are exceptions.
617-18870	Quartz (gold) SiO_2	Central mine, Lava Cap Gold Mining Company, Nevada City, California	White	nuv	The quartz gangue in a few other ores of metals has been noted to fluoresce.

313-19618	Scheelite, $CaWO_4$	Atolia mine, Atolia, San Bernardino County, California	Light blue	uv	One of several hundred specimens from almost as many locations from all over the world. All fluoresce, most a pale blue, others white, yellow to green. All give a good brilliancy.
209 and 806-19285	Smithsonite, $ZnCO_3$	Cerro Gordo mine, Inyo County, California	Lavender	nuv	Fluoresces the same color as fluorite from Cumberland, England, and is equally brilliant.
806	Wernerite (scapolite)	Ontario, Canada	Yellow	nuv	Very brilliant; this specimen fluoresces from rays from the lower end of the visible spectrum, and its brilliancy is equally good with all lights used. Window glass placed between the source of light and the specimen did not retard the fluorescence.
806 and 129-18084	Willemite, Zn_2SiO_4	Franklin Furnace, New Jersey	Green	uv	This mineral fluoresces with all types of lights tried but shows the greatest brilliancy with those giving the shorter wave-lengths. Most willemite from Franklin Furnace is associated with calcite that fluoresces red with the shorter wave-lengths. Most specimens of willemite from Franklin Furnace give green phosphorescence.
130-20924	Zircon, $ZrSiO_4$	Lincoln, Placer County, California	Golden yellow	uv	One of many samples tried from different locations. All fluoresced a yellow of varying intensity, with the[1] exception of one which did not fluoresce. Fluorescent zircon has been found in the black sand concentrates from placer mining operations in many parts of California.

[1] Case and number of specimen in the Museum of the Division of Mines, Ferry Building, San Francisco, California.
[2] Name of mineral giving fluorescence.
[3] Location from which mineral originally came.
[4] Color of fluorescence.
[5] Approximate wave-length of ultra-violet light exciting fluorescence; nuv=near ultra-violet, 3,400 to 4,000 A.U.; uv=middle ultra-violet, 2,500 to 3,400 A.U.
[6] Case No. 806 is equipped with ultra-violet lights for the display of fluorescent minerals.

Hence to get the best results in a display of fluorescent minerals, two different types of ultra-violet lights are needed.

Our first special case for exhibiting fluorescent minerals was a box 40 inches square with a pyramidal top. One side of the pyramidal part was equipped with a full window, the other three sides with peek-holes. Inside was a 36-inch revolving tray divided into four segments by vertical curtains. As the tray revolved, the specimens were seen in daylight through the window and in three different kinds of ultra-violet light in the other compartments. One compartment was equipped with a 22-inch NiCo tube, the second compartment with a Model 361 Mineralight, the third with a bank of five argon bulbs. This case gave fairly good results, but its capacity was so limited that it was replaced.

The present case (No. 806) for exhibiting fluorescent minerals is a shadow-box 7 feet long, 3 feet 4 inches wide, and 4 feet 8 inches high. The upper part of the front is inclined at 45° with the horizontal and equipped with a window 5 feet long and 6 inches wide. White light is furnished by three ordinary incandescent bulbs along the back, which are controlled by a push-button. Ultra-violet light of two different kinds is provided. One ultra-violet light is a 50-inch NiCo tube controlled by a time-switch, the other is a 30-inch cold quartz tube controlled by a push-button. Specimens are placed on shelves running lengthwise and spaced with centers at equal distances from the NiCo tube. This case gives good results, but daylight entering through the window is objectionable. Fluorescence is best observed in a dark room.

A few experiments have been made with the transmission of ultra-violet light through specimens of clear, transparent minerals. Pieces of quartz, calcite, selenite (clear gypsum) and halite (salt), 2 inches in thickness, seem to offer practically no resistance to the passage of ultra-violet light. Specimens of fluorescent minerals emit about the same amount of light when one of these minerals is placed in the beam of ultra-violet light as when it is removed. Clear barite, celestite and sylvite cut off the shorter wave-lengths of ultra-violet. Ordinary glass and thin sheets of muscovite mica, when placed in the beam of ultra-violet light, cut off practically all of the ultra-violet, and only one mineral, wernerite, fluoresced under these conditions. This mineral fluoresces under the shortest wave-lengths of the visible spectrum (about 4000 A. U.).

Experiments have been made with the fluorescence of several minerals under water. The ultra-violet light was kept at a constant distance from the mineral and the depth of the water was gradually increased. Little difference was noted in the fluorescence while the water was shallow, but the amount of light emitted by minerals fluorescing under the shorter wave-lengths (uv) gradually decreased as the depth of water increased.

The preceding table lists a few of the minerals in our exhibit that showed good or outstanding fluorescence. Specimens were examined under a General Electric H4 light in red-purple envelope (nuv) and under a Mineralight model 361 (uv). Many more minerals were found to fluoresce than was originally expected. More specimens fluoresce under the longer wave-lengths of ultra-violet (nuv) than under the shorter wave-lengths (uv). For a more definite record of the color of light emitted by fluorescent minerals, the wave-length in Ångström units of positions of principal bands in the spectrum should be given, but apparatus for this is not available at the Division of Mines. General information on this point is contained in the work of Pringsheim and Vogel cited above.

FLUORESCENT MINERALS USED IN LIGHTING AND ELSEWHERE[1]

By Oliver C. Ralston[2] and A. George Stern[3]

CONTENTS

PURPOSE OF THIS REPORT

Fluorescence is of growing interest to the mineral industry because certain minerals may be detected thereby and because many minerals (natural or synthetic) are needed in tubes and lamps. The use of fluorescent lighting is expanding, and large numbers of lamps of many sizes and shapes are being made and used in works, factories, stores, offices, homes, and in photography. Fluorescent tubes, as distinguished from clear tubes filled with neon, argon, or other rare gases through which a current of electricity passes, fluoresce owing to specially selected and prepared minerals placed in the tubes. Luminous chemicals and paints also contain special minerals and are used in similar applications; therefore, these also will be considered in this report.

Although the quantity of minerals (in tons) that are used for fluorescent purposes is small, and probably will continue to be so, this use is significant because it exemplifies a requirement for "pure" minerals in which a trace of contaminant as minute as one part in ten million may distinguish between the acceptance or rejection of a particular material. This extreme purity makes synthetic minerals almost essential, and natural minerals are now little used.

Interest in fluorescent lighting has become so lively recently that this brief report has been prepared to answer a few of the numerous questions that arise in connection with minerals related to fluorescence.

---

[1] Reprinted from U. S. Bureau of Mines Information Circular 7276.
[2] Chief, Industrial Minerals Division, Bureau of Mines.
[3] Chemical engineer, Bureau of Mines.

FLUORESCENCE—WHAT IT IS

The fundamental principles of fluorescence are discussed by Fonda.[4] At a low order of brightness, it is found in many organic products of our daily life and in minerals. Fluorescent solids among artificially prepared products are known as "phorphors," and the fluorescence is frequently associated with the presence of a foreign ingredient at a very low concentration—a fraction of 1 percent. The light emitted during radiation by the exciting source is known as "fluorescence." Often, the fluorescent substance continues to emit light for a time after the exciting source is extinguished. Such a decaying emission of light is known as "phosphorescence."

A ground and polished filter of dark ultraviolet transmitting glass in front of a quartz arc holds back the visible light emitted by a mercury-quartz burner and allows only a concentrated beam of invisible ultraviolet radiations to pass, thereby producing what has been termed a "black ray." Various common substances absorb these invisible radiations, change (increase) their wave lengths (these all travel at the same speed in free space) and re-emit them as colored light visible to the eye. This light emission is fluorescence.

Hartman,[5] Philadelphia maker of luminous paints, explains fluorescent lighting as follows:

> Certain mineral substances possess the rare property of absorbing ultra-violet rays and re-emitting them in longer wave lengths. [These rays are part of the invisible spectrum and are found at the violet end, being observable only when all visible light rays are eliminated. Therefore, this luminescence is most effective in the dark.] One such mineral substance will re-radiate this light in a certain shade of red, another will produce a certain blue effect, and so on throughout the entire band of visible color frequencies. It is only necessary to select the proper minerals, combine them properly, and use them as pigment in this specially developed paint, to create any desired color effect.
>
> In ordinary light, such as daylight or incandescent electric light, these paints appear just as ordinary pale tints. But when other light is at least partly excluded, and violet rays are employed as a light source, any surfaces treated with these colors immediately become fluorescent, and are brilliantly radiated in the form of colored light. However, there is no radio-activity involved, and the paints, the process of illumination, and the whole scheme are entirely harmless to human tissue.

The term "fluorescent lighting" can be used in two respects, according to Costello [6]—first, to describe the new fluorescent tubes, and, second, for "black light" in conjunction with fluorescent paints. When any material is treated with such paints, the white light turned off and the "black light" turned on, the latter will radiate invisible ultraviolet rays, which will cause the fluorescent-treated materials to re-emit light according to the colors of the pigments used in the paints.

DEFINITIONS

Some confusion in terminology exists among the various authorities frequently consulted; therefore, in the following an attempt is made to state definitions of luminescence, fluorescence, and phosphorescence that describe the phenomena as they seem to be understood by the fluorescent-lighting industry. Other definitions to be considered are found in (1) Webster's New International Dictionary (Merriam & Co., Springfield, Mass., 1939); (2) Ford's Dana's Textbook of Mineralogy (John Wiley &

[4] Fonda, G. R., Elec. Eng., vol. 58 December 1938, pp. 677-681.
[5] Hartman, Frank: Broadcast News, April 1935.
[6] Costello, Charles, Black-Ray Lighting Co., Cleveland, Ohio.

Sons, New York City, 4th ed., 1932) ; and (3) Weld's Glossary of Physics (McGraw-Hill Book Co., New York, 1937). Bryson [7] considers the distinction between the three terms arbitrary, and his suggestions have been considered in the following definitions.

Luminescence. This is a broad term covering any emission of light not ascribable directly to incandescence and therefore occurring at low temperatures, as in the firefly. This term includes a long series of phenomena, such as fluorescence, phosphorescence, triboluminescence, chemiluminescence, crystalloluminescence, electroluminescence, cathodoluminescence, and thermoluminescence.

Fluorescence. The property of emitting radiation from within a substance exposed to direct radiation or electrical discharges in a gas-filled or vacuum tube is known as fluorescence. This phenomenon is well-exhibited by the mineral fluorite. The emitted radiation is longer in wave length than the absorbed radiation, and therefore commercial practice applies violet or ultraviolet light, X-rays or various electronic bombardments as the exciting radiation to get emitted radiation in the visible spectrum. After the exciting radiation is discontinued, the fluorescence is extinguished at various rates.

Phosphorescence. When the afterglow of a fluorescent substance exceeds 10^{-6} seconds (and in some instances it lasts for several days), the phenomenon is described as phosphorescence—namely, fluorescence that continues for a time after excitation is discontinued.

Phosphors. Fluorescing and phosphorescing subtsances are called phosphors. Most of the industrial applications are with synthesized minerals or organic substances, because naturally occurring materials have proved too erratic and unreliable.

FLUORESCENT LIGHTING

The phenomenon of fluorescence has been familiar to scientists for several hundred years, and the idea of a fluorescent lamp is not in itself a new one. The colored, fluorescent, advertising-sign tubing has been a familiar sight for some years, but until now fluorescence has not been used for general lighting.

The fundamental principle of the fluorescent lamp involves merely transforming electrical energy into invisible ultraviolet radiation and this into visible light by exposing chemical powders, known as phosphors, to the direct rays of ultraviolet or X rays.

The ability of a gas or vapor to become "luminescent," that is, to give off light under the influence of the flow of electrons through it, involves a somewhat intricate theory of the structure of atoms. Popular explanations of this theory usually resort to the idea of a "collision" of the speedy electrons with the atoms of the gas. When these encounters take place, there is a state of excitation that produces light. To attempt to explain the theory of fluorescence would introduce more complications than are involved in explaining the production of light directly by the flow of electrons through a gas. Materials that do fluoresce have the property of absorbing energy at one wave length and reradiating it at a longer wage length somewhat as do transformers or some radio tubes, which absorb energy at one voltage and current and deliver it at another.

---

[7] Bryson, H. Courtney, Luminescent Pigments and Paints: Oil and Colour Trades Jour., London, vol. 96, December 1939, pp. 1181-1396 (intermittent) ; vol. 97, January 1940, pp. 33-139 (intermittent) ; February 1940, pp. 245-247.

How It Operates

Fluorescent lamps are commonly tubular with an electrode sealed in each end, and are coated inside with special fluorescent powders, which glow when stimulated by short-wave ultraviolet light. The dimensions of the tube usually are within the limits 18 to 60 inches in length and 1 to $2\frac{1}{8}$ inches in diameter, but other sizes may become available. The peculiar ultraviolet light (and some visible light) is produced within the tube by a low-pressure electric discharge in mercury vapor (with a little argon present) between two preheated small coils of tungsten wire, which act as electrodes. The resulting fluorescence produces a rich, bright glow, either artificial daylight or a deep, beautiful color, from the entire coated surface of the glass tube.

According to Cox,[8] a method of coating the inside of the lamp deposits the phosphors in a sort of porous film on the walls of the bulb, so that it may absorb a relatively greater amount of the ultraviolet energy and deliver a proportionally greater amount of visible light.

Various powders emit their radiant energy at different wave lengths, with the result that a variety of colors can be produced through different mixtures of the phosphor compounds.

In describing his luminous tube, Beck[9] covers the progress of illumination as follows (his composite ''daylight'' light is formed by blending neon light, mercury light, and incandescent light) :

> The progress of the illumination art and corresponding industry has been marked by well-defined epochs and corresponding inventions. The oil lamp, used as long ago as the dawn of the Christian era, continued to be used until the discovery of illuminating gas. This was superseded by the Edison carbon-filament incandescent lamp. This was followed by the now widely used tungsten-filament lamp, in which a filament of tungsten was substituted for the Edison carbon filament. Toward the end of the nineteenth century and in the early years of the present century, attempts were made to utilize the light emitted when a discharge of electricity is passed through a column of gas at low pressure, for example, air, nitrogen, carbon dioxide, contained in elongated tubes known as Moore tubes. These were commercially unsuccessful, largely because the gas filling become depleted very rapidly. Somewhat more successful were the Cooper-Hewitt mercury-vapor lamps, in which a discharge of electricity occurs between electrodes in an atmosphere of mercury vapor. For special purposes these lamps find application, but they are substantially monochromatic, or at least the spectrum of the light emitted is so predominantly in the blue region that the human skin assumes a ghastly appearance. These lamps are quite useless for general illuminating purposes.
>
> When the rare gases of the atmosphere, for example, neon, became available in commerial quantities, the practically dead art of illumination by discharge of electricity between electrodes in an atmosphere of gas was in a sense born again, because means were discovered whereby a tube having a filling of neon and provided with suitable electrodes would have a period of useful commercial life. But, like the Cooper-Hewitt mercury-vapor lamp, the neon tube or lamp emits a substantially monochromatic light in the red end of the spectrum, and while such a light is of great value for display purposes, it is useless as a general illuminant.
>
> Throughout the history of the lamp art, the problem of securing a commercially satisfactory lamp having substantially the same effect as daylight has ever been present.

With the development of the present-day fluorescent tube, this has been accomplished; today, any desired combination of colors may be obtained by careful selection of the minerals to be used for coating the inner walls of the fluorescent tube.

The following advantages for fluorescent lighting have been pointed out:

[8] Cox, J. L., Luminescent Coating for Electric Lamps: U. S. Patent 2,096,693, October 19, 1937.

[9] Beck, Leo L., Luminous Tube: U. S. Patent 2,012,236, August 20, 1935.

1. *High efficiency.* Greater illumination is now possible without increase in consumption of wattage.

2. *Cool light.* Only one quarter the radiant heat and half the total heat of ordinary incandescent electric lamps of the same light output is emitted. In this way, the load on air conditioning is greatly reduced, and tasks performed under intense light, which formerly were unpleasantly hot for the operator, now can be performed in cool comfort. The operating tubes can be touched without discomfort.

3. *Daylight quality.* The "daylight" lamp is the most efficient source of artificial daylight available. Indoor illumination without excessive heat, which closely approximates natural daylight, permits color examination and comparison heretofore possible only in daylight or by use of highly inefficient filters with incandescent lamps.

4. *Colored light.* Pastel shades of light may be produced directly with the fluorescent lamp.

5. *Avoidance of shadows and glare.* Instead of an almost point source of light from the incandescent lamp, the fluorescent lamp offers a comparatively glareless tube of light with almost complete absence of shadows.

Uses in the Mineral Industry

General Lighting

The fluorescent tube or lamp, whose light is more effective than that of the incandescent lamp, is used widely in mining plants. The "white" tube, which is somewhat more efficient than the daylight lamp, is preferred for many applications, both because of this and because of its warmer color. In contrast with the incandescent lamp, shadows are less intense, the light being well diffused, and when two fluorescent lamps are operated as a pair, flicker is almost eliminated.

Fluorescent lamps have a longer life when used more or less continuously and in planning to use them for plant illumination it should be recognized that switching them off and on unnecessarily shortens their life far more than constant use. The amount of heat emitted by fluorescent tubes is low, and for equal light emission the fluorescent tube consumes approximately one-third the power required by the tungsten incandescent lamp.

It seems probable that the fluorescent lamp will find increased use in mine change-houses, hoisting rooms, power plants, coal-preparation buildings, several types of milling and treatment plants, and in many metal-manufacturing operations.

The effects of vibrations are not so serious as with incandescent lamps, but where crushed rock is likely to fly, it would be advisable to protect the lamps with wire screening. Good illumination means better and safer work, including less strain on the eyes and easier vision, and it is claimed that fluorescent lighting offers all these.

Regarding the benefits to be derived from better lighting, an editorial entitled "Factory Lighting"[10] points out:

> The provision of good lighting is not philanthropy. The right type of lighting in the right place has been shown to result in better-quality work and a higher production rate. And these benefits can often be obtained at a lower cost than if obsolete lighting methods are employed. Some months ago we drew attention to a windowless factory for high-precision engineering work, in which reliance was deliberately placed on artificial light provided by fluorescent tubes.

[10] The Metal Industry, Factory Lighting: London, March 29, 1940.

Fluorescent lamps are suitable, also, for mine-office and laboratory work—clerical, drafting, and reading of plans. An adjustable "floating" arm or bracket and reflector for an 18- by 1-inch, 15-watt, fluorescent, daylight tube is available for table or desk use. This lamp is cool and does not concentrate the heat, as does the incandescent lamp; in use, the lamp should not be too high above the job.

Extreme variations in temperature lower the efficiency of fluorescent lamps, and therefore, for outdoor illumination, it seems advisable to protect the lamp and to approximate "room temperature."

Mineral Examination

For several years, the value of fluorescence as a means of detecting certain minerals has been recognized. As early as 1916, an ultraviolet apparatus was described by Andrews,[11] who used a spark-gap as a source of ultraviolet light. For examining tungsten ores, Vanderburg [12] suggested that ultraviolet rays afford a simple means for determining scheelite ores and mill products. Scheelite fluoresces bright light blue when activated by ultraviolet rays emitted by a high-tension disruptive spark between iron terminals.

Portable equipment for use in mines was described by Vandeburg [13] as developed jointly by O. F. Heizer [14] and Paul F. Kerr.[15] The apparatus weighed about 18 pounds, had a small transformer, which stepped up 110 to 120 volts a.c. to 4,500 volts, a mica condenser, and a spark-gap with adjustable and replaceable iron electrodes, as well as switch and other accessories. It was similar to Andrews' design but had a quartz projecting lens and was designed particularly for the detection of scheelite underground. Especially striking in the total darkness of a mine, the fluorescence of this mineral offers a simple and reliable method for qualitative (and rough quantitative) determination. Units of less weight are now commercially available.

In concentrating scheelite ores, such an instrument is useful in estimating the percentages of scheelite in jig, table, and magnetic-separator products to test their efficiencies. A sample of the dried material is placed under the spark lamp, and the amount of scheelite in the sample can be approximated by its fluorescence. The fluorescence of scheelite does not show as readily in a lighted room on the finer material as on the coarser material. A dark or well-shaded room is necessary for best results. Because chemical methods of assaying for tungsten are slow and expensive, they are seldom, if ever, used in routine mill-control in tungsten plants. Ordinarily, methods based upon the specific gravity of the tungsten minerals are employed. With scheelite, the ultraviolet apparatus is more rapid than panning, and, because of the greater area available for exposure, it gives a better average.

The New Jersey Zinc Co. also uses this ultraviolet light in the examination of zinc-mineral products to control the operation of the concentrating machines of their ore from Franklin Furnace, New Jersey.

---

[11] Andrews, W. S., Apparatus for Producing Ultraviolet Radiation: General Electric Review, vol. 19, April 1916, pp. 317-319.

[12] Vanderburg, W. O., Mining and Milling Tungsten Ores: Bureau of Mines Inf. Circ. 6852, 1935, 47 pp.

[13] Vanderburg, W. O., A Note on the Use of Ultraviolet Lamps in Mines for Rapid Determination of Scheelite in Ores by Fluorescence: Bureau of Mines Inf. Circ. 6873, 1936, 3 pp.

[14] Manager, Nevada-Massachusetts Co., Inc., Mill City, Nev.

[15] Associate professor of Mineralogy, Columbia University, New York.

Instead of the spark gap as a source of ultraviolet light, the argon lamp became available recently as a cheap and simple source. Also, a blue fluorescent lamp serves as an effective source. Both of these work directly from the ordinary lighting circuit on 110 volts. However, the amount of light emitted is low (from a 5-watt lamp, it is 1/100 of that of a 125-watt mercury-discharge lamp). To receive adequate excitation, a substance must be placed as close as possible to the lamp.

Another source of ultraviolet light is the mercury-discharge lamp of the Cooper-Hewitt type, which is expensive and runs at a high temperature. Until recently, however, it was one of the important sources of ultraviolet light.

"Black Light"

The recent development of quartz-arc lights with accompanying glass filters, identified as ''black light,'' has greatly simplified the problem of obtaining an inexpensive but intense source of ultraviolet light for mineral examination as well as other purposes where ultraviolet light alone (with almost no visible rays) is desired. It is available in a simple holder similar to that of a ''photoflood'' lamp, with compact transformer, easily portable, and constructed so that it can be connected to the regular lighting circuit.

This improvement eliminates the necessity for constructing a special box, as described above, and now several commercial units suitable for use in mineral examination are available.

The so-called ''black light'' is attained by placing a filter of dark-colored ultraviolet transmitting glass in front of an ultraviolet quartz-arc bulb, which holds back the visible light emitted by the powerful mercury quartz burner and allows only a concentrated beam of invisible ultraviolet radiations, ranging between 2,400 A and 4,250 A, to pass.

FLUORESCENT MINERALS

Natural Minerals

Several common minerals, such as calcium, fluorine, and zinc, fluoresce when subjected to the influence or excitation of ultraviolet rays. Other minerals do not themselves fluoresce but do so when certain other mineral compounds or activators are contained in their composition.

To attain a pure color of specified wave length or combination of wave lengths for illumination with fluorescent tubes, minerals of exceptionally high purity are required. Natural minerals usually do not have the requisite degree of purity. This is evident when it is realized that one part of foreign matter in ten million is enough to adulterate a mineral and cause its rejection as ''impure.'' Rare exceptions of suitable natural minerals may be pointed out, but for practical purposes it is more dependable to synthesize the minerals under carefully controlled conditions, so that each batch will be as nearly identical to other batches as possible.

Many natural minerals are fluorescent, however, and these will be mentioned briefly even though they are not suitable for use by the fluorescent lighting industry.

Calcium minerals. According to Ford's Dana,[16] several of the calcium minerals, especially the calcites, fluoresce. Of these, calcite

[16] Ford's Dana's Textbook of Mineralogy: John Wiley & Sons, New York, 4th ed., 1932, 851 pp.

($CaCO_3$) and fluorite (CaF_2) frequently show the property quite strongly; also, to some extent, do aragonite ($CaCO_3$), gypsum ($CaSO_4.2H_2O$), scheelite ($CaWO_4$), and olivine uranite or hydrous phosphate of uranium and calcium ($Ca(UO_2)_2P_2O_8.8H_2O$).

The luminescence of calcite has been known for many years. Some investigators found calcite to be active and others found it to be inactive; two of them held that luminescence is not inherent in calcite but due to traces of foreign substance in solid solution. Calcite from Franklin Furnace, N. J., was subjected to excitation with the iron spark and by cathode bombardment.[17] The phosphorescence under photo-excitation is of the vanishing type, has a ruddy color, and a duration of about 0.4 second. Under cathode-excitation, the phosphorescence is persistent, red in color, and measurable 300 seconds after excitation. The characteristic ruddy phosphorescence appeared to be due to the presence of traces of manganese. Calcium carbonate artificially prepared is rendered similarly phosphorescent by the addition of the proper small amount of manganese salt followed by heat treatment.

In describing the preparation of fluorescent calcite, Fonda[18] ascribed the red fluorescence of the natural calcite occurring at Franklin to the presence of manganese as the activator. The most successful method of preparation was precipitation of the calcium carbonate from solution in the presence of a manganese salt. As the manganese content was increased, the fluorescence rose to a peak and then decreased. Déribére[19] tested 45 samples of calcareous substances. These also indicate that manganese and strontium are luminogens or activators.

Zinc minerals. Zinc sulfide or sphalerite, ZnS, and zinc silicate or willemite, Zn_2SiO_4, are the common fluorescent minerals. The former is common, whereas the latter is mined in quantity only in New Jersey associated with zincite, the red oxide of zinc, ZnO, and with franklinite $(Fe,Zn,Mn)O.(Fe,Mg)_2O_3$, a zinc-iron manganese mineral. Willemite is reddish to greenish and under a fluorescent lamp is a brilliant greenish-white.

Other minerals. Although there are other natural minerals, such as those containing tungsten, barium, strontium, beryllium, and cadmium, that show fluorescence, and also the fossil resin, amber (a hydrocarbon mineral), they are not sufficiently important to justify individual consideration.

Synthetic Minerals

It is so difficult to obtain a natural mineral that is relatively pure and contains the correct but small proportion of another mineral, that it has been found simpler and more direct to synthesize the minerals, as mentioned above, and thus obtain the desired combinations and proportions. Traces of impurities are very disadvantageous when unwanted and can be avoided by synthesis. Therefore, minerals for use in fluor-

[17] Nichols, E. L., Howes, H. L., and Wilber, D. T. The Photoluminesence and Cathodoluminescence of Calcite: The Physical Review, vol. 12, November 1918, pp. 351-367.

[18] Fonda, G. R., The Preparation of Fluorescent Calcite: Jour. Phys. Chem., vol. 44, April 1940, pp. 435-439.

[19] Déribére, Maurice, The Luminescent Minerals: Calcareous Substances: Ann. Soc. Geol. Belgique, Bull. 62, 1938-39, pp. 156-162.

escent lighting are mostly synthetic, and it is not expected that any substantial tonnage of natural minerals will be mined and consumed directly for this purpose.

Bryson[20] states that commercial phosphorescent pigments are complex phosphors, such as alkaline-earth sulfides, activated by a heavy metal and fluxed with salts. The base material or solvent may be a compound of calcium, barium, strontium, magnesium, beryllium, sodium, or zinc; the activator and the flux, a colorless inorganic salt of low melting point, such as sodium sulfate, potassium sulfate, sodium chloride, borax, or potassium nitrate; a body yielding sulfur, selenium, oxygen, or carbonate; and a reducing agent. Some of these preparations phosphoresce for many hours after illumination.

Zinc sulfide. Bryson[21] states that synthetic zinc sulfide is both phosphorescent and fluorescent when properly prepared. It possesses great technical importance and, because it is a simple compound (ZnS), it has received more study than any other luminescent compound. Luminescent zinc sulfide activated with copper is a cream-colored powder fluorescing brilliantly under a "black" lamp and normally exhibiting a fairly long decay period, although not as long as the less-stable phosphorescent strontium sulfide.

In the preparation of zinc sulfide, for example, Bryson states that several processes may be used, but, whatever the method, no metal apparatus should come in contact with the mineral being prepared. A usual procedure involves passing purified hydrogen sulfide into a solution of slightly acidified zinc sulfate, rejecting the first impure precipitate, adding ammonia and sodium to precipitate heavy metals, and then continuing to pass hydrogen sulfide until all the zinc sulfide is down. The copper, generally present to the extent of 0.005 percent, may be coprecipitated or added later. Firing is done in silica or very pure clay tubes or crucibles used once and then discarded. Fluxes may be added during the firing.

Beryllium compounds. For the manufacture of fluorescent tubes, an almost c.p. grade of beryllium oxide is prepared,[22] which is 99.8 percent BeO with impurities not to exceed 0.04 percent CaO, 0.02 percent Al_2O_3, 0.05 percent SiO_2, 0.05 percent Fe_2O_3, and 0.01 percent undecomposed sulfate.

The beryllium oxide is then used in making zinc beryllium silicate and other synthetic beryllium minerals. They are some of the commercially important phosphors.

Important "phosphors." The number of synthetic minerals used in fluorescent lighting is increasing rapidly, and a complete list is not possible, but the General Electric Co. of Schenectady, N. Y., has tabulated those fluorescent chemicals known as "phosphors" that are most widely used, together with their fluorescent properties.

In modern fluorescent tubes, a mixture of most or all of these phosphors in carefully combined proportions is used, so that the fluorescence produced by the resulting blend will closely approximate the desired "color spectrum."

---

[20] See footnote 7.
[21] See footnote 7.
[22] Foote Mineral Co., Philadelphia, Pa.

Fluorescent chemicals (phosphors) [1]

Phosphor	*Color*	*Exciting range A* [2]	*Sensitivity peak A*	*Emitted range A*	*Emitted peak A*
Calcium tungstate	Blue	2200-3000	2720	3800-7000	4400
Magnesium tungstate	Blue-white	2200-3200	2850	3800-7200	4800
Zinc silicate	Green	2200-2960	2537	4500-6200	5250
Zinc beryllium silicate	Yellow-white	2200-3000	2537	4500-7200	5950
Cadmium silicate	Yellow-pink	2200-3200	2400	4300-7200	5950
Cadmium borate	Pink	2200-3600	2500	4000-7200	6150

[1] In addition to the phosphor, manganese is usually present as an activator.
[2] 2200A is the lower limit of measurement.

Activation of Minerals

As previously stated, when certain materials are constituents of some minerals, they become fluorescent. Some impurities are important contributors to luminescence, or they can suppress luminescence. Iron, cobalt, nickel, copper, zinc, manganese, silver, tin, rubidium, antimony, thallium, lead, bismuth, uranium, and samarium are common activators. An activator is an important constituent of phosphors. It should enter the crystal lattice, and widely different amounts are required in the same solvent to obtain optimum results (0.000000024 percent bismuth or 0.04 percent manganese to activate calcium sulfide to maximum brilliance, for example). Iron sometimes is detrimental, 0.00000005 percent being fatal to calcium sulfide phosphors activated with bismuth. One of the most frequently used activators is manganese, and in the minerals used in most fluorescent tubes a trace of manganese salt usually is included.

A recent issue of Collier's [23] shows brilliant color photographs of luminescent materials taken by their own light. Pure willemite and the pure sulfides of barium, calcium, and strontium will not luminesce at all; they require the addition of some other metal, termed an "activator." The amount necessary is extremely small, in some instances as little as 1 part activator in 10 million parts of mineral. It and all other materials used must be as nearly pure as human ingenuity can devise, and all operations are conducted with that in mind.

FLUORESCENT SCREENS

For most purposes, a fluorescent material should have a slow rate of extinguishment, so that its effect will last as long as possible. However, for television screens, a rapid rate of extinguishment is highly important, and the objective is to regulate it so that an image on a particular spot of the screen will last for the fraction of the second until the next cycle and be completely extinguished at that moment, so that no overlap will occur. By glowing for about 1/50 second after excitation, flickerless pictures with more detail become possible.[24]

For viewing the image in the electron microscope, a fluorescent screen (or a photographic plate) is required. When the stream of electrons strikes a fluorescent screen, it produces an image that can be seen by the human eye. Since useful magnifications of 50,000 or even more, in comparison to 2,000 diameters magnification in an ordinary microscope, are obtained, it is important that the fluorescent screen be carefully selected and prepared so that maximum precision may be obtained.

[23] White, Owen P., Man-Size Television: Collier's, March 16, 1940, pp. 58-59.
[24] Industrial Bulletin of Arthur D. Little, Inc., May 1940.

Recently a fluorescent theatre-aisle carpet, in which fluorescent dye was used in preparing the yarn, was installed in a New York moving-picture theatre. It is activated to a visible glow by ultraviolet flash lights carried by the ushers [25] or by black lamps attached to the seats.

Another novel use for phosphorescent material is for producing echos in a microphone circuit.[26] Here, a fairly rapid rate of extinguishment of the phosphor (complete fading in a few seconds) is desired.

Three classes of fluorescent materials are widely used to convert the electrical energy of the electron beam into light (as, for example, in the cathode-ray tubes used in television receivers)—silicates, sulfides, and tungstates: [27]

"*Silicates.* The silicates are stable, relatively high in optical efficiency, and not changed appreciably by small amounts of impurities. The zinc-beryllium silicate system with manganese as an activator, gives a variety of colors from green to deep orange. Zinc silicate (willemite) with a medium persistence green luminescence is used commonly in oscillograph tubes.

"*Sulphides.* The zinc-cadmium sulphide system, activated with silver or copper, gives colors over the entire visible spectrum, from deep blue for zinc sulphide to deep red for cadmium sulphide. Silver activation produces materials with short persistence; copper is used as an activator for materials with long persistence such as oscillograph tubes where it is desired to have a trace remain visible on the screen for several seconds after the electron beam has been cut off. Mixtures of a blue zinc sulphide, activated with silver, and a yellow zinc-cadmium sulphide (or a yellow zinc-beryllium silicate) are used in producing white pictures on television screens. The stability of the sulphides is not so high as that of the silicates, and the former are very susceptible to changes of characteristics resulting from minute traces of heavy metal impurities.

"*Tungstates.* The tungstates are nonactivated fluorescent materials. Their colors vary from a deep blue for calcium tungstate to a light-white for cadmium, zinc, or magnesium tungstates. Their very short persistence makes screens of these materials useful in the photography of high-speed transients."

In London, during the night black-outs, phosphorescent paints are used to reveal the vague general outlines of traffic obstacles and vehicles. Phosphorescent paints [28] with a period of decay of over 12 hours are desirable to continue to phosphoresce for most of the night after daylight illumination has been withdrawn.

In mines and buildings, the use of phosphorescent paints near the usual electric lamps will provide a faint marker in case power fails and lights are extinguished. A trail of such phosphorescent markers in a mine or a cave should be of value for such eventualities. Phosphorescent knobs on pull-chain switches of electric lights have been known for some time. Important valves, levers, and controllers may be rendered phosphorescent. The safety engineer of a mine or an operating plant, provided with a container of phosphorescent paint, will find numerous places where its use will increase safety. Phosphorescent employees' badges increase convenience in identification. A board striped with a number of phosphorescent paints which luminesce in different colors, and each color, with a definite period of decay, will constitute a record of time since lights were extinguished or since strong lights passed the recording point. Military uses of phosphorescent paint are numerous. Road signs, traffic hazards, and markers, if phosphorescent, can increase safety.

---

[25] See footnote 24.

[26] Goldmark, Peter C., Phosphorescent Materials for Producing Echos: U. S. Patent 2,203,352, June 4, 1940. From Science News Letter, July 13, 1940, p. 24.

[27] Monack, A. J., Materials for Vacuum-Tube Manufacture: Ind. and Eng. Chem., vol. 32, No. 8, pp. 1028-1033.

[28] Skinner, G. D., Luminous Porcelain Enamel for Signs, Storefronts, and Other Uses: The Enamelist, vol. 17, August 1940, pp. 6-8.

7—38463

LUMINESCENT PIGMENTS, PAINTS, AND INKS

Although the manufacture of luminescent pigments and paints consumes minerals, in this paper attention is directed more especially to the use of minerals in the illumination source itself; yet, some reference to it is in order, especially as there are a number of manufacturers of luminous paints and pigments in the United States.

In an extensive technical review of luminescent pigments and paints, Bryson [29] defines terms and follows with sections on zinc sulfide and radium paints; the manufacture of alkaline earth phosphors, with its many careful operations, such as proper heat treatment, correct grinding, effect of impurities and activators; effect of temperature; characteristics of some sulfide phosphors (strontium sulfide, calcium sulfide, barium sulfide, zinc sulfide); luminous paints, and how to use them; and concludes with an extensive bibliography of 320 references.

An ever-luminous paint activated by radioactive elements involves the use of fluorescent minerals in combination with the radioactive element to provide a continuous stream of electrons, gammarays, or X-rays to activate the fluorescent minerals, is an old and well-known article. They serve better on objects that usually remain in the dark. Articles and instruments in dark rooms may be marked for convenience in locating them and avoiding accidents as long as the radioactive paint is not to be near stored photosensative film and paper.

Invisible fluorescent ink is used by laundries for indelibly marking shirts and other washables to permit subsequent identification under the ultraviolet light, although the marking is not evident under usual illumination.

The fluorescent screens used in X-ray laboratories for viewing an object directly without waiting for development of the photographic plate are well known. X-rays are of still shorter wave length than ultraviolet light. In taking photographs by X-ray, the radiographs can receive enough effective illumination to justify very short exposure if a fluorescent intensifying screen is introduced next the photographic film to be caused to glow by the incident energy and increase the amount of effective light. Tasker recently patented a calcined barium sulfate that can lower the exposure time to 1/50th of the time needed for the bare film alone. The pigment is mounted on paper of suitable size, and the paper is installed behind the photographic film. The barium sulfate must be free of iron, manganese, chromium, copper, nickel, or cobalt, but it may contain as much as 10 to 20 per cent of the sulfates of strontium or calcium. It is calcined for 6 to 10 hours at 1,000 to 1,060°C. to activate it.

SUMMARY

Minerals play an important part in fluorescent lighting, but their purity must be so great that in almost every instance synthetic minerals must be used. Those that seem to be most useful for fluorescent use are silicate, sulfide, tungstate compounds of zinc, beryllium, and cadmium. A manganese compound usually is present as an activator.

Not only are these minerals used in fluorescent tubes for converting ultraviolet light and X-rays into visible illumination but also to make screens that will convert the energy waves into visible light, and also for the identification of minerals by studying their fluorescent characteristics.

---

[29] See footnote 7.

CALIFORNIA MINERAL PRODUCTION FOR 1943

By Henry H. Symons *

Tabulations are presented herein showing the complete totals for all substances produced in California during the year 1943, grouped by substances and by counties. The complete detailed annual report on the mineral production of California for 1943 will be available later as Bulletin 128 of the State Division of Mines.

The total value of the mineral output of California for the year 1943 was $426,445,280, being an increase of $17,706,846 over the total of 1942 which was $408,738,434. The increase was due to stimulated output owing to war demand. There were sixty different mineral substances, exclusive of a segregation of various stones grouped under gems; all fifty-eight counties of the State contributing to the list.

As revealed by the following, the salient features of 1943 as compared with the previous year were: Increases in total value were registered by such groups of mineral substances as fuels, industrial materials, and salines, while the metals and structural materials showed a decline in total value. Of the year's mineral output, petroleum showed the greatest increase in value, followed in turn by natural gas, iron ore, copper, diatomite, chromite, quicksilver, zinc, gem materials, tungsten ore, etc. Decreases were registered by gold, cement, miscellaneous stone, silver, brick and hollow building tile, etc. The greatest annual values for their output in California were recorded by bromine, diatomite, dolomite, gypsum, iron ore, iodine, limestone, magnesium salts, molybdenum ore, quicksilver, soda, and tungsten ore.

Of the fuels, petroleum showed an increase in value of $46,841,861 and an increase in amount from 247,491,289 barrels to 284,145,702 barrels of crude oil. The 1943 output of petroleum was the largest in amount with the exception of that of 1929 when 292,534,221 barrels were produced. The amount of natural gas utilized increased from 413,180,942 M. cu. ft., worth $25,698,052, to 443,219,847 M. cu. ft., worth $28,046,729, and was the largest annual consumption from this State, and its value was only exceeded by that of 1929.

Of the metals, an increase in annual value was recorded in all materials except gold, silver, and the platinum group metals. The value of the gold yield decreased from $29,679,895 in 1942 to $5,191,480 in 1943 which is the smallest annual output in both amount and value since 1848 when gold was discovered in California, and for the first time the value of other metals; namely quicksilver and tungsten, exceeded that of gold and the increases in values were not enough to offset that of gold. Copper increased from 2,138,149 lbs., worth $258,716, to 17,172,440 lbs., worth $2,232,417; quicksilver increased from 30,087 flasks, worth $5,553,357, to 33,948 flasks, worth $6,177,159; and tungsten ore from 231,201 units, worth $5,586,770, to 254,118 units, worth $5,910,745.

Of the structural materials, all materials classed under this group showed a decline in production from 1942. Cement decreased from 23,306,578 barrels, worth $35,808,841, to 18,515,085 barrels, worth $27,865,466; miscellaneous stone decreased from a total value of $27,281,342 to $21,716,223; and brick and hollow building tile decreased from a total value of $5,708,967 to $4,368,675.

Of the industrial materials, the group as a whole increased in total value from $8,606,428 to $10,706,955, with such items as barite, bentonite, diatomite, dolomite, gem materials, gypsum, limestone, mineral water, pyrite, and talc and soapstone showing increased outputs, and carbon dioxide, pottery clay, pumice and volcanic ash, slate, and strontium minerals a decreased value.

Of the saline group, the total value increased from $15,645,003 to $15,660,400, with slight increases in value registered by borates, bromine, calcium chloride, iodine, magnesium salts, potash, and soda; and with salt the only substance under this classification to show a decline in output.

Distribution of the 1943 output of California by substances

Substance	*Amount*		*Value*	*Number of properties*
Bentonite	11,480	tons	$118,257	4
Borates	216,687	tons	4,953,174	5
Brick and hollow bldg. tile	------		4,368,675	35
Carbon dioxide	227,424	M. cu. ft.	248,126	3
Cement	18,515,085	bbls.	27,865,466	12
Clay (pottery)	622,019	tons	1,185,240	41
Copper	17,172,440	lbs.	2,232,417	(f)
Dolomite	331,251	tons	472,756	4
Gems	------		329,868	6
Gold	148,328	fine ozs.	5,191,480	(a)
Granite	------		148,160	10
Gypsum	495,967	tons	916,883	8
Iron ore	907,458	tons	2,341,827	7
Lead	11,811,034	lbs.	885,827	(f)
Limestone	495,262	tons	1,378,647	19
Magnesium salt	9,026	tons	728,065	4
Mineral water	22,022,314	gals.	814,700	35
Natural gas	443,219,847	M. cu. ft.	28,046,729	(b)
Petroleum	284,145,702	bbls.	289,323,406	(b)
Pumice and volcanic ash	21,154	tons	142,665	9
Quicksilver	33,948	flasks	6,177,159	86
Salt	631,776	tons	1,695,231	9
Silica (quartz and glass sand)	161,318	tons	533,434	10
Silver	609,075	fine ozs.	433,120	(a)
Soapstone and talc	63,012	tons	723,056	12
Soda (soda ash and salt cake)	260,590	tons	3,166,576	5
Miscellaneous stone (c)	32,499,456	tons	21,716,223	186
Tungsten	254,118	units	5,910,745	39
Zinc	5,170,627	lbs.	558,427	(f)
Unapportioned (d)	------		13,838,941	
Total value			$426,445,280	

(a) There were 139 lode mines and 82 placer mines, not including snipers, prospectors, and various individuals who sold small lots.
(b) There was an average of 19,477 producing wells.
(c) Includes macadam, crushed rock, ballast, rubble, rip rap, sand and gravel.
(d) Includes asbestos (2), barite (2), bituminous rock (2), bromine (3), calcium chloride (1), chromite (66), coal (1), diatomite (3), feldspar (2), iodine (2), lithia (1), magnesite (3), manganese ore (58), mineral paint (1), molybdenum ore (1), platinum group metals (e), potash (1), pyrite (1), sandstone (2), sillimanite group (2), slate (1), paving blocks (1), tube-mill pebbles (1), strontium (2), titanium (1).
(e) Platinum group metals mined before 1943 by dredging company but not sold until then.
(f) Included with gold.

Distribution by counties for 1943

County	*Value*	*Number of mineral products*
Alameda	$5,336,917	9
Alpine	20,241	2
Amador	534,098	10
Butte	755,968	9
Calaveras	2,831,543	12
Colusa	93,486	2
Contra Costa	4,284,821	9
Del Norte	609,664	3
El Dorado	304,449	10
Fresno	41,039,427	12
Glenn	915,030	2
Humboldt	237,827	9
Imperial	685,203	7
Inyo	8,025,406	15
Kern	94,245,359	18
Kings	16,015,695	4
Lake	798,381	5
Lassen	25,353	2
Los Angeles	100,688,245	18
Madera	55,575	7
Marin	280,119	5
Mariposa	443,693	9
Mendocino	82,480	6
Merced	1,118,313	5
Modoc	28,691	2
Mono	56,205	8
Monterey	1,142,800	7
Napa	948,557	6
Nevada	890,647	10
Orange	28,068,896	11
Placer	277,283	13
Plumas	207,509	8
Riverside	5,452,740	12
Sacramento	6,588,998	10
San Benito	3,528,462	7
San Bernardino	22,042,939	30
San Diego	1,650,586	11
San Francisco	432,500	1
San Joaquin	1,621,661	8
San Luis Obispo	1,037,062	8
San Mateo	3,041,434	5
Santa Barbara	16,830,725	9
Santa Clara	8,128,250	10
Santa Cruz	2,900,752	6
Shasta	3,766,717	12
Sierra	176,016	5
Siskiyou	1,896,246	9
Solano	4,931,944	3
Sonoma	1,521,314	6
Stanislaus	1,112,486	12
Sutter	74,905	2
Tehama	72,917	2
Trinity	323,123	9
Tulare	301,292	8
Tuolumne	783,508	8
Ventura	25,080,976	7
Yolo	365,176	3
Yuba	1,734,670	5
Total value	$426,445,280	

ACCESSIONS TO THE EXHIBIT

By Henry H. Symons *

The museum of the State Division of Mines possesses an exceptionally fine collection of rocks and minerals of economic and academic value. It ranks among the first five such collections in North America and contains not only specimens of most of the known minerals found in California, but much valuable and interesting material from other States and foreign countries as well.

The exhibit is daily visited by engineers, students, business men and prospectors as well as tourists and sightseers. In addition to its practical use in the economic development of California's mineral resources, the collection is a most valuable educational asset to the State and to San Francisco.

Mineral specimens suitable for exhibit purposes are solicited, and their donation will be appreciated by the Division of Mines, as well as by those who utilize the facilities of the collection.

Among the specimens received recently and catalogued for the exhibit are the following:

21157 PHOSPHATE ROCK from Kirov, State of Karelia, U. S. S. R. Donor: Walfrid Heino, 331 Alameda Street, Astoria, Oregon. February 1944. In case 141.

21158 CASSITERITE (SnO_2), twinned crystal. From Belmonte, Portugal, mine of Portuguese-American Tin Company. Donor: W. E. Thorne, Placerville, California. June 1944.

21159 CASSITERITE (SnO_2), twinned crystal. From Nigeria, Central Africa. Donor: W. E. Thorne, Placerville, California. June 1944.

21160 CASSITERITE (SnO_2), stream tin. From Buck Creek, Alaska, a few miles north of York. Donor: W. E. Thorne, Placerville, California. June 1944.

21161 DOLOMITE from Kaiser property, between Hinkley and Hodge, San Bernardino County. Donor: O. P. Jenkins. June 1944. In case 400.

21162 MAGNETITE (iron ore) from Bessemer mine, Bessemer Valley, sec. 28, T. 6 N., R. 4 E., S. B., 30 miles southeast of Daggett, San Bernardino County, California. Donor: O. P. Jenkins. June 1944. In case 306.

21163 CASSITERITE in limestone associated with iron-bearing calcite. True granite found 100 feet away. From 6 miles east of Gorman, Kern County, California. Donor: O. P. Jenkins. June 1944. In case 312.

21164 MAGNESIUM METAL from Permanente Metals, Permanente, Santa Clara County, California. Donor: T. B. Blevins, Jr., Route 1, Box 52, Saratoga, California. June 1944. In case 230.

21165 HEMATITE in quartz from northwest of Shoshone, Inyo County (east of Death Valley), California. Donor: H. B. Ward, 512 Hobart Building, San Francisco, California. June 1944. In case 209.

* Statistician and Curator, Division of Mines.

LIBRARY

LIBRARY REPORT

By JAMES M. LITTLE *

OUTLINE OF REPORT

INTRODUCTION

The library of the Division of Mines contains more than 6,000 selected volumes on mines, mining, and allied subjects. It is also the repository for reports and bulletins of technical departments of Federal and State governments and educational institutions both domestic and foreign. Current copies of newspapers published in the mining centers of the State are also available for reference.

The library has a card file system for references to individual California mines recorded or described in the publications of the Division of Mines, in the Mining and Scientific Press, the Engineering and Mining Journal, and the Arizona Mining Journal.

The library and reading room are open to the public during the usual office hours, when the librarian may be freely called upon for all necessary assistance.

PUBLICATIONS OF THE UNITED STATES GEOLOGICAL SURVEY AND UNITED STATES BUREAU OF MINES

The library of the Division of Mines has available for public reference the following publications of the United States Geological Survey: Annual Reports, Monographs, Professional Papers, Bulletins, Water-Supply Papers, Mineral Resources, Folios of the Geologic Atlas of the United States (broken file), Maps with Descriptive Text (broken file), Administrative Publications (broken file); and the following publications of the United States Bureau of Mines: Bulletins, Technical Papers, Economic Papers (broken file), Mineral Resources of the United States, Monographs (broken file), Reports of Investigations, Information Circulars.

* Librarian, Division of Mines.

Ten topographic maps have recently been received from the United States Geological Survey. They are:

Auburn quadrangle, Placer and El Dorado Counties, 1944, scale 1:62,500.
Cuyamaca Peak quadrangle, San Diego County, 1944, scale 1:62,500.
Fluornoy quadrangle, Tehama and Glenn Counties, 1944, scale 1:62,500.
Hernandez Valley quadrangle, San Benito and Monterey Counties, 1944, scale 1:62,500.
Oroville quadrangle, Butte County, 1944, scale 1:62,500.
Potrero quadrangle, San Diego County, 1944, scale 1:62,500.
Priest Valley quadrangle, Fresno and Monterey Counties, 1944, scale 1:62,500.
Raymond quadrangle, Madera and Mariposa Counties, 1944, scale 1:62,500.
Sutter Creek quadrangle, Amador and Calaveras Counties, 1944, scale 1:62,500.
Wilbur Springs quadrangle, Colusa and Lake Counties, 1944, scale 1:62,500.

PUBLICATIONS OF STATE SURVEYS

A broken file of mining and geological publications, issued by the State organizations (except California) listed below, may be consulted at the Division of Mines Library.

Alabama Geological Survey, University.
Alaska (Territorial Commissioner of Mines), Juneau.
Arizona Bureau of Mines, Tucson.
Arkansas Geological Survey, Little Rock.
Colorado Bureau of Mines, Denver.
Connecticut Geological and Natural History Survey, Hartford.
Florida Department of Conservation, Tallahassee.
Georgia Division of Geology, Atlanta.
Idaho Bureau of Mines and Geology, Moscow.
Idaho Inspector of Mines, Boise.
Illinois Geological Survey, Urbana.
Indiana Division of Geology, Indianapolis.
Iowa Geological Survey, Des Moines.
State Geological Survey of Kansas, Lawrence.
Kentucky Geological Survey, Frankfort.
Louisiana Department of Conservation, New Orleans.
Maine State Geologist, Augusta.
Maryland Geological Survey, Baltimore.
Michigan Geological Survey, Lansing.
Minnesota Geological Survey, Minneapolis.
Mississippi State Geological Survey, University.
Missouri Bureau of Geology and Mines, Rolla.
Montana Bureau of Mines and Geology, Butte.
Nebraska Geological Survey, Lincoln.
Nevada State Bureau of Mines, Reno.
New Jersey Department of Conservation and Development, Trenton.
New Mexico Bureau of Mines and Mineral Resources, Socorro.
New York Science Division, Albany.
North Carolina Geological and Economic Survey, Chapel Hill.
North Dakota Geological Survey, Grand Forks.
Ohio Geological Survey, Columbus.
Oklahoma Geological Survey, Norman.
Oregon State Department of Geology and Mineral Industries, Portland.
Pennsylvania Topographic and Geological Survey, Harrisburg.
South Dakota State Geological Survey, Vermillion.
Tennessee Division of Geology, Nashville.
Texas Bureau of Economic Geology, Austin.
Virginia Geological Survey, University.
Washington State Department of Conservation and Development, Pullman.
West Virginia Geological Survey, Morgantown.
Wisconsin Geological and Natural History Survey, Madison.
Wyoming Geological Survey, Cheyenne.

PUBLICATIONS OF FOREIGN GOVERNMENTS

Publications of the following departments of foreign governments are received and current issues may be consulted in the library. Earlier issues of foreign-language publications have been loaned to the California Academy of Sciences in Golden Gate Park, because of the limited storage space at the Divisions' offices in the Ferry Building. They may, however, be consulted at the Academy.

Alberta Research Council, Edmonton.
Argentina Direccion General de Minas y Geologica, Buenos Aires.
British Columbia Minister of Mines, Victoria.
British Museum of Natural History, London.
Canada Department of Mines, Ottawa.
Cuerpo de Ingenieros de Minas y Aguas del Peru, Lima.
Direccion General de Minas y Petroleo, Mexico City.
Direction of Mines, Dakar, French West Africa.
Geological Service of Minas Geraes, Bella Horizonte, Brazil.
Geological Survey of Canada, Ottawa.
Geological Survey of Scotland.
Instituto Historica e Geographico, Rio de Janeiro.
Museo de Historia Natural de Montevideo, Uruguay.
Museu Nacional, Rio de Janiero.
New South Wales Department of Mines, Sydney, Australia.
New Zealand Geological Survey Branch, Wellington.
Nova Scotia Department of Public Works and Mines, Halifax.
Ontario Department of Mines, Toronto, Canada.
Quebec Bureau of Mines, Quebec.
Queensland Department of Mines, Brisbane, Australia.
Service of Mines, Brazzaville, French Equatorial Africa.
South Australia Department of Mines, Adelaide.
Transvaal Chamber of Mines, Johannesburg, South Africa.
Western Australia Geological Survey, Perth.

PUBLICATIONS OF FOREIGN AND DOMESTIC SOCIETIES AND EDUCATIONAL INSTITUTIONS

Academia de Ciencias y Artes de Barcelona, Spain.
Academy of Natural Sciences of Philadelphia.
American Association of Petroleum Geologists, Tulsa, Oklahoma.
American Geographical Society of New York.
American Institute of Mining and Metallurgical Engineers, New York.
American Journal of Science, New Haven, Conn.
American Philosophical Society, Philadelphia.
Australian Museum, Sydney.
California Academy of Sciences, San Francisco.
Canadian Institute of Mining and Metallurgy, Montreal.
Carnegie Institution of Washington.
Cleveland Museum of Natural History, Cleveland, Ohio.
Colorado College Publications, Colorado Springs.
Colorado Scientific Society, Denver.
Commonwealth Club, San Francisco.
Economic Geology, Lancaster, Pennsylvania.
Field Museum of Natural History, Chicago.
Franklin Institute of the State of Pennsylvania, Lancaster.
Geological Society of America, Columbia University, New York.
Geological Society of London.
Institution of Mining and Metallurgy, London.
Instituto de Mineralogia y Geologia, Universidad de Tucuman, Argentina.
Instituto Geologico de Mexico, Mexico, D. F.
Journal of Geology, Chicago.
Mineralogical Society of America, Menasha, Wisconsin.

Michigan College of Mining and Technology, Houghton.
Mining and Metallurgical Society of America, New York.
Missouri School of Mines and Metallurgy, Rolla.
Museu Nacional, Rio de Janeiro.
National Research Council, Washington, D. C.
New York Academy of Sciences, New York.
New York State Museum, Albany.
Pennsylvania State College, State College.
Philippine Journal of Science, Manila.
Royal Society of South Australia, Adelaide.
Seismological Society of America, Stanford University.
Sierra Club, San Francisco.
Society of Economic Paleontologists and Mineralogists, Fort Worth, Texas.
Southern California Academy of Sciences, Los Angeles.
Stanford University, Palo Alto, California.
University of California Publications in Engineering, Geography, and Geology, Berkeley.
University of California Publications in Geography, Berkeley.
University of California Publications in Geology, Berkeley.
University of Harvard, Department of Mineralogy and Petrography, Cambridge, Mass.

CURRENT MAGAZINES

Current issues of the technical magazines listed below are on file in the reading room of the library, and may be consulted.

Asbestos, Philadelphia, Pennsylvania.
Brick and Clay Record, Chicago.
California Magazine of the Pacific, San Francisco.
California Mining Journal, Auburn.
California Oil World, Los Angeles.
California Safety News, San Francisco.
Canadian Mining Journal, Gardenvale, Quebec.
Chemical and Metallurgical Engineering, New York City.
Chemical Engineering and Mining Review, Melbourne, Australia.
Civil Engineering, New York City.
Colorado School of Mines, Golden, Colorado.
Engineering and Mining Journal, New York City.
Fusion Facts, Whittier, California.
Gold, Toronto, Canada.
Grizzly Bear, Los Angeles.
Hercules Mixer, Wilmington, Delaware.
Independent Monthly, Tulsa, Oklahoma.
Lubrication, The Texas Co., New York City.
Metals and Alloys, Pittsburg, Pennsylvania.
Mineralogist, Portland, Oregon.
Mining and Contracting Review, Salt Lake City.
Mining Congress Journal, Washington, D. C.
Mining and Industrial News, San Francisco.
Mining and Geological Journal, Melbourne, Victoria, Australia.
Mining Journal, London.
Mining Journal, Phoenix, Arizona.
Mining and Metallurgy, New York City.
Mining World, Seattle.
Nickel Steel Topics, New York City.
Northwest Mining News, Spokane, Washington.
Oil and Gas Journal, Tulsa, Oklahoma.
Oil, Paint and Drug Reporter, New York City.
Oil Weekly, Houston, Texas.
Pacific Purchaser, San Francisco.
Petroleum World, Los Angeles.
Queensland Government Mining Journal, Brisbane, Australia.
Rock Products, Chicago.
Rocks and Minerals, Peekskill, New York.

Scientific American, New York City.
Southwest Builder and Contractor, Los Angeles.
Standard Oil Bulletin, San Francisco.
Stone, New York City.
Western Mining News, San Francisco.

NEWSPAPERS

Current issues of the following papers are received and kept on file in the library:

Alaska Weekly, Seattle, Washington.
Amador Dispatch, Jackson, California.
Banner, Sonora, California.
Barstow Printer, Barstow, California.
Bridgeport Chronicle-Union, Bridgeport, California.
Calaveras Californian, Angels Camp, California.
Calaveras Prospect, San Andreas, California.
Daily Commercial News, San Francisco, California.
Del Norte Triplicate, Crescent City, California.
Denver Mining Record, Denver, Colorado.
Inyo Independent, Independence, California.
Inyo Register, Bishop, California.
Las Vegas Age, Las Vegas, Nevada.
Livermore Herald, Livermore, California.
Los Angeles Times, Los Angeles, California.
Mariposa Gazette, Mariposa, California.
Mining Press, Reno, Nevada.
Mohave Miner, Kingman, Arizona.
Morning Union, Grass Valley, California.
Mountain Messenger, Downieville, California.
Needles Nugget, Needles, California.
Oroville Mercury Register, Oroville, California.
Placer Herald, Auburn, California.
Placerville Times, Placerville, California.
Plumas Independent, Quincy, California.
Randsburg Times, Randsburg, California.
Tehachapi News, Tehachapi, California.
Terra Bella News, Terra Bella, California.
Tuolumne Independent, Sonora, California.
Tuolumne Prospector, Tuolumne, California.
Union Democrat, Sonora, California.
Weekly Trinity Journal, Weaverville, California.
Yreka Journal, Yreka, California.

NEW BOOKS

Recent accessions to the library are the following books:

League of Nations, International Currency Experience. 249 pp., New York, Columbia Press, 1944. (F. W. Bradley Memorial Book Fund).

Brooks, T. B., Peace, Plenty and Petroleum. 197 pp., Lancaster, Pennsylvania, The Jacques Cattell Press, 1944. (F. W. Bradley Memorial Book Fund).

SERVICES OF THE DIVISION OF MINES

The Division of Mines (formerly State Mining Bureau) is maintained for the purpose of assisting in all possible ways in the development of California's mineral resources.

As one means of offering tangible service to the mining public, the State Mineralogist for many years has issued an annual or a biennial report reviewing in detail the mines and mineral deposits of the various counties.

As a progressive step in advancing the interests of the mineral industry, and as permitting earlier distribution to the public, publication of the Annual Report of the State Mineralogist in the form of monthly chapters was begun in January 1922, and continued until March 1923. Owing to a lack of funds for printing this was changed to a quarterly publication, beginning in September 1923. For the same reason, beginning with the January 1924 issue, it became necessary to charge a subscription price. This covers approximately the cost of printing.

Pages are numbered consecutively throughout the year and an index to the complete report is included annually in the closing number.

Beginning with the 1930 issues, the activities and progress of the Geologic Branch are recorded also in these quarterly chapters. The important part that geology plays in the economic development of our mineral resources is further recognized in the change of title from *Mining in California* to CALIFORNIA JOURNAL OF MINES AND GEOLOGY, beginning with the January 1933 chapter.

While current activities of all descriptions are covered in these chapters, the practice of issuing from time to time technical reports on special subjects will be continued as well. A list of such reports now available is appended hereto, and the names of new bulletins will be added in the future as they are completed.

The chapters are subject to revision, correction and improvement. Constructive suggestions from the mining public will be gladly received, and are invited.

The one aim of the Division of Mines is to increase its usefulness and to stimulate the intelligent development of the wonderful, latent resources of the State of California.

TYPES OF REPORTS

In general the reports presented in these chapters are grouped into three classes:

1. Mines and mineral resources of a given county or area (describing kind, character, distribution and extent of development).

2. Specific economic and industrial mineral products (listing and describing the resources over the entire State of a given mineral substance, e.g., feldspar).

3. Geological reports on specific areas (recording results and conclusions with maps, derived from field studies; and tied in with economic possibilities and developments).

Reports of District Mining Engineers

In 1919-1920 the Mining Bureau was organized into four main geographical divisions, with the field work delegated to a mining engineer in each district, working out from field offices that were established in Redding, Auburn, San Francisco and Los Angeles, respectively. This move brought the office into closer personal contact with operators, and it has many advantages over former methods of conducting field work, including lower traveling-expense bills for the Bureau's engineers. In 1923 the Redding and Auburn field offices were consolidated and moved to Sacramento.

The Redding office was reestablished in 1928, and the boundaries of each district adjusted. The counties now included in each of the four divisions and the locations of the branch offices are shown on the frontispiece outline map of the State.

Reports of mining activities and development in each district, prepared by the District Engineer, will continue to appear under the proper field division heading.

Special Articles

Detailed technical reports on special subjects, the result of research work or extended field investigations, will continue to be issued as separate bulletins by the Division, as has been the custom in the past.

Shorter and less elaborate technical papers and articles by members of the staff and others are published in each number of CALIFORNIA JOURNAL OF MINES AND GEOLOGY.

These special articles cover a wide range of subjects both of historical and current interest; descriptions of new processes, or metallurgical and industrial plants, new mineral occurrences, and interesting geological formations, as well as articles intended to supply practical and timely information on the problems of the prospector and miner, such as the text of new laws and official regulations and notices affecting the mineral industry.

MAIL AND FILES

The Division of Mines maintains, in addition to its correspondence files and the library, a mine file which includes original reports on the various mines and mineral properties of all kinds in California.

During each quarterly period there are several thousand letters received and answered at the San Francisco office alone, covering almost every phase of prospecting, mining and developing mineral deposits, reduction problems, marketing of refined products and mining law. In addition to this, hundreds of oral questions are answered daily, both at the main office and the district offices, for the many inquirers who come in for personal interviews and to consult the files and library.

COMMERCIAL MINERAL NOTES

The producer and consumer of mineral products are mutually dependent upon each other for their prosperity, and one of the most direct aids rendered by this Division to the mining industry in the past has been that of bringing producers and consumers into direct touch with each other.

This work has been carried on largely by correspondence, supplemented by personal consultation. Lists of buyers of all the commercial minerals produced in California have been made available to producers upon request, and likewise the owners of undeveloped deposits of various minerals, and producers of them, have been made known to those looking for raw mineral products.

When the publication of *Mining in California* was on a monthly basis, current inquiries from buyers and sellers were summarized and lists of mineral products or deposits 'wanted' or 'for sale' included in each issue.

It is important that inquiries of this nature reach the mining public as soon as possible and in order to avoid the delay incident to the present quarterly publication of CALIFORNIA JOURNAL OF MINES AND GEOLOGY, these lists are now issued monthly in the form of a mimeographed sheet under the title of 'Commercial Mineral Notes,' and sent to those on the mailing list of CALIFORNIA JOURNAL OF MINES AND GEOLOGY.

EMPLOYMENT SERVICE

Following the establishment of the Mining Division branch offices in 1919, a free technical employment service was offered as a mutual aid to mine operators and technical men for the general benefit of the mineral industry.

Briefly summarized, men desiring positions are registered, the cards containing an outline of the applicant's qualifications, position wanted, salary desired, etc., and as notices of 'positions open' are received, the names and addresses of all applicants deemed qualified are sent to the prospective employer for direct negotiations.

Telephone and telegraphic communications are also given immediate attention.

Technical men, or those qualified for supervisory positions, and vacancies of like nature only, are registered, as no attempt will be made to supply mine and mill labor.

Registration cards for the use of both prospective employers and employees may be obtained upon request, and a cordial invitation is extended to the industry to make free use of the facilities afforded. Parties interested should communicate direct with our San Francisco office.

DETERMINATION OF MINERAL SAMPLES

Samples (limited to two at one time) of any mineral found in the State may be sent to the Division of Mines for identification, and the same will be classified free of charge. No samples will be determined if received from points outside the State. It must be understood that no assays, or quantitative determinations will be made. Samples should be in lump form if possible, and marked plainly with name of sender on outside of package, etc. No samples will be received unless delivery charges are prepaid. A letter should accompany sample, giving locality where mineral was found and the nature of the information desired.

PUBLICATIONS OF THE DIVISION OF MINES

During the past sixty-four years, in carrying out the provisions of the organic act creating the former California State Mining Bureau, there have been published many reports, bulletins and maps which go to make up a library of detailed information on the mineral industry of the State, a large part of which could not be duplicated from any other source.

One feature that has added to the popularity of the publications is that many of them have been distributed without cost to the public, and even the more elaborate ones have been sold at a price which barely covers the cost of printing.

Owing to the fact that funds for advancing the work of this department have usually been limited, the reports and bulletins mentioned are printed in limited editions many of which are now entirely exhausted.

Copies of such publications are available for reference, however, in the offices of the Division of Mines, in the Ferry Building, San Francisco; State Building, Los Angeles; State Office Building No. 1, Sacramento; Redding; and Division of Oil and Gas at Santa Barbara, Santa Paula, Taft, Bakersfield, Coalinga. They may also be found in many public, private and technical libraries in California and other states and foreign countries.

A catalog of all publications from 1880 to 1917, giving a synopsis of their contents, is issued as Bulletin No. 77.

Publications in stock may be obtained postpaid by addressing the San Francisco, Los Angeles or Sacramento offices and enclosing the requisite amount.

Remittances of stamps in an amount not to exceed 26 cents, currency or coin will be accepted at sender's risk. Payment is preferred in the form of money orders.

Money orders should be made payable to the Division of Mines.

Write for latest revised price list.

NOTE.—The Division of Mines frequently receives requests for some of the early Reports and Bulletins now out of print, and it will be appreciated if parties having such publications and wishing to dispose of them will advise this office.

REPORTS

Asterisks (**) indicate the publication is out of print.

Price (including postage and sales tax)

**First Annual Report of the State Mineralogist, 1880, 43 pp. Henry G. Hanks ----

**Second Annual Report of the State Mineralogist, 1882, 514 pp., 4 illustrations, 1 map. Henry G. Hanks ----

**Third Annual Report of the State Mineralogist, 1883, 111 pp., 21 illustrations. Henry G. Hanks ----

**Fourth Annual Report of the State Mineralogist, 1884, 410 pp., 7 illustrations. Henry G. Hanks ----

**Fifth Annual Report of the State Mineralogist, 1885, 234 pp., 15 illustrations, 1 geological map. Henry G. Hanks ----

**Sixth Annual Report of the State Mineralogist, Part I, 1886, 145 pp., 3 illustrations, 1 map. Henry G. Hanks ----

Part II, 1887, 222 pp., 36 illustrations. William Irelan, Jr. Price $0.75, sales tax $0.02 $0.77

**Seventh Annual Report of the State Mineralogist, 1887, 315 pp. William Irelan, Jr. ----

**Eighth Annual Report of the State Mineralogist, 1888, 948 pp., 122 illustrations. William Irelan, Jr. ----

**Ninth Annual Report of the State Mineralogist, 1889, 352 pp., 57 illustrations, 2 maps. William Irelan, Jr. ----

**Tenth Annual Report of the State Mineralogist, 1890, 983 pp., 179 illustrations, 10 maps. William Irelan, Jr. ----

Eleventh Report (First Biennial) of the State Mineralogist, for the two years ending September 15, 1892, 612 pp., 73 illustrations, 4 maps. William Irelan, Jr. Price $1.50, sales tax $0.04 1.54

**Twelfth Report (Second Biennial) of the State Mineralogist, for the two years ending September 15, 1894, 541 pp., 101 illustrations, 5 maps. J. J. Crawford ----

**Thirteenth Report (Third Biennial) of the State Mineralogist, for the two years ending September 15, 1896, 726 pp., 93 illustrations, 1 map. J. J. Crawford ----

Chapters of the State Mineralogist's Report, XIV Biennial Period, 1913, 1914, Fletcher Hamilton:

**Mines and Mineral Resources, Amador, Calaveras and Tuolumne Counties, 172 pp., paper ----

Mines and Mineral Resources, Colusa, Glenn, Lake, Marin, Napa, Solano, Sonoma and Yolo Counties, 208 pp., paper Price $0.50, sales tax $0.01 .51

**Mines and Mineral Resources, Del Norte, Humboldt and Mendocino Counties, 59 pp., paper ----

**Mines and Mineral Resources, Fresno, Kern, Kings, Madera, Mariposa, Merced, San Joaquin and Stanislaus Counties, 220 pp., paper ----

**Mines and Mineral Resources of Imperial and San Diego Counties, 113 pp., paper ----

**Mines and Mineral Resources, Shasta, Siskiyou and Trinity Counties, 180 pp., paper ----

**Fourteenth Report of the State Mineralogist, for the Biennial Period 1913-1914, Fletcher Hamilton, 1915:

A General Report on the Mines and Mineral Resources of Amador, Calaveras, Tuolumne, Colusa, Glenn, Lake, Marin, Napa, Solano, Sonoma, Yolo, Del Norte, Humboldt, Mendocino, Fresno, Kern, Kings, Madera, Mariposa, Merced, San Joaquin, Stanislaus, San Diego, Imperial, Shasta, Siskiyou and Trinity Counties, 974 pp., 275 illustrations, cloth ----

Chapters of the State Mineralogist's Report, XV Biennial Period, 1915-1916, Fletcher Hamilton:

**Mines and Mineral Resources, Alpine, Inyo and Mono Counties, 176 pp., paper ----

Mines and Mineral Resources, Butte, Lassen, Modoc, Sutter and Tehama Counties, 91 pp., paper Price $0.50, sales tax $0.01 .51

REPORTS—Continued

Asterisks (**) indicate the publication is out of print.	Price (including postage and sales tax)
**Mines and Mineral Resources, El Dorado, Placer, Sacramento and Yuba Counties, 198 pp., paper	----
**Mines and Mineral Resources, Monterey, San Benito, San Luis Obispo, Santa Barbara and Ventura Counties, 183 pp., paper	
Mines and Mineral Resources, Los Angeles, Orange and Riverside Counties, 136 pp., paper — Price $0.60, sales tax $0.02	$0.62
**Mines and Mineral Resources, San Bernardino and Tulare Counties, 186 pp., paper	----
**Fifteenth Report of the State Mineralogist, for the Biennial Period 1915-1916, Fletcher Hamilton, 1917: A General Report on the Mines and Mineral Resources of Alpine, Inyo, Mono, Butte, Lassen, Modoc, Sutter, Tehama, Placer, Sacramento, Yuba, Los Angeles, Orange, Riverside, San Benito, San Luis Obispo, Santa Barbara, Ventura, San Bernardino and Tulare Counties, 990 pp., 413 illustrations, cloth	----
Chapters of the State Geologist's Report XVI, Biennial Period, 1917-1918, Fletcher Hamilton:	
**Mines and Mineral Resources of Nevada County, 270 pp., paper	----
Mines and Mineral Resources of Plumas County, 188 pp., paper — Price $0.50, sales tax $0.01	.51
Mines and Mineral Resources of Sierra County, 144 pp., paper — Price $0.75, sales tax $0.02	.77
Seventeenth Report of the State Mineralogist, 1920, 'Mining in California during 1920,' Fletcher Hamilton; 562 pp., 71 illustrations, cloth — Price $2.50, sales tax $0.06	2.56
Eighteenth Report of the State Mineralogist, 1922, 'Mining in California,' Fletcher Hamilton. Chapters published monthly beginning with January, 1922:	
**January, **February, **March, **April, **May, **June, July, August, September, **October, November, **December, 1922 — Price $0.30, sales tax $0.01	.31
Chapters of Nineteenth Report of the State Mineralogist, 'Mining in California,' Fletcher Hamilton and Lloyd L. Root. January, February, March, September, 1923 — Price $0.30, sales tax $0.01	.31
Chapters of Twentieth Report of the State Mineralogist, 'Mining in California,' Lloyd L. Root. Published quarterly. January, April, October, 1924, per copy — Price $0.30, sales tax $0.01	.31
Chapters of Twenty-first Report of the State Mineralogist, 'Mining in California,' Lloyd L. Root. Published quarterly:	
January, 1925, Mines and Mineral Resources of Sacramento, Monterey and Orange Counties — Price $0.30, sales tax $0.01	.31
**April, 1925, Mines and Mineral Resources of Calaveras, Merced, San Joaquin, Stanislaus and Ventura Counties	----
**July, 1925, Mines and Mineral Resources of Del Norte, Humboldt and San Diego Counties	----
**October, 1925, Mines and Mineral Resources of Siskiyou, San Luis Obispo and Santa Barbara Counties	----
Chapters of Twenty-second Report of the State Mineralogist, 'Mining in California,' Lloyd L. Root. Published quarterly:	
**January, 1926, Mines and Mineral Resources of Trinity and Santa Cruz Counties	----
**April, 1926, Mines and Mineral Resources of Shasta, San Benito and Imperial Counties	----
July, 1926, Mines and Mineral Resources of Marin and Sonoma Counties — Price $0.30, sales tax $0.01	.31
**October, 1926, Mines and Mineral Resources of El Dorado and Inyo Counties, also report on Minaret District, Madera County	----

8—38463

REPORTS—Continued

Asterisks (**) indicate the publication is out of print. Price (including postage and sales tax)

Chapters of Twenty-third Report of the State Mineralogist, 'Mining in California,' Lloyd L. Root. Published quarterly:

January, 1927, Mines and Mineral Resources of Contra Costa County; Santa Catalina Island-----Price $0.30, sales tax $0.01	$0.31
April, 1927, Mines and Mineral Resources of Amador and Solano Counties Price $0.30, sales tax $0.01	.31
**July, 1927, Mines and Mineral Resources of Placer and Los Angeles Counties -----	----
October, 1927, Mines and Mineral Resources of Mono County----- Price $0.30, sales tax $0.01	.31

Chapters of Twenty-fourth Report of the State Mineralogist, 'Mining in California,' Lloyd L. Root. Published quarterly:

January, 1928, Mines and Mineral Resources of Tuolumne County----- Price $0.30, sales tax $0.01	.31
April, 1928, Mines and Mineral Resources of Mariposa County----- Price $0.30, sales tax $0.01	.31
**July, 1928, Mines and Mineral Resources of Butte and Tehama Counties--	----
October, 1928, Mines and Mineral Resources of Plumas and Madera Counties-----Price $0.30, sales tax $0.01	.31

Chapters of Twenty-fifth Report of the State Mineralogist, 'Mining in California,' Walter W. Bradley. Published quarterly:

January, 1929, Mines and Mineral Resources of Lassen, Modoc and Kern Counties; also on Special Placer Machines--Price $0.30, sales tax $0.01	.31
**April, 1929, Mines and Mineral Resources of Sierra, Napa, San Francisco and San Mateo Counties-----	----
July, 1929, Mines and Mineral Resources of Colusa, Fresno and Lake Counties -----Price $0.30, sales tax $0.01	.31
October, 1929, Mines and Mineral Resources of Glenn, Alameda, Mendocino and Riverside Counties-----Price $0.30, sales tax $0.01	.31

Chapters of Twenty-sixth Report of the State Mineralogist, 'Mining in California,' Walter W. Bradley. Published quarterly:

January, 1930, Mines and Mineral Resources of Santa Clara County; also Barite in California-----Price $0.40, sales tax $0.01	.41
**April, 1930, Mines and Mineral Resources of Nevada County; also Mineral Paint Materials in California-----	----
**July, 1930, Mines and Mineral Resources of Yuba and San Bernardino Counties; also Commercial Grinding Plants in California-----	----
October, 1930, Mines and Mineral Resources of Butte, Kings and Tulare Counties; also Geology of Southwestern Mono County (Preliminary) Price $0.40, sales tax $0.01	.41

Chapters of Twenty-seventh Report of the State Mineralogist, 'Mining in California,' Walter W. Bradley. Published quarterly:

January, 1931. Preliminary Report of Economic Geology of the Shasta Quadrangle. Beryllium and Beryl. The New Tariff and Nonmetallic Products. Crystalline Talc. Decorative Effects in Concrete----- Price $0.40, sales tax $0.01	.41
April, 1931, Stratigraphy of the Kreyenhagen Shale. Diatoms and Silicoflagellates of the Kreyenhagen Shale. Foraminifera of the Kreyenhagen Shale. Geology of Santa Cruz Island----- Price $0.40, sales tax $0.01	.41
**July, 1931. (Yuba, San Bernardino.) Feldspar, Silica, Andalusite and Cyanide Deposits of California. Note on a Deposit of Andalusite in Mono County; its occurrence and chemical importance. Bill creating Trinity and Klamath River Fish and Game District and its effect upon mining -----	----
October, 1931. (Alpine.) Geology of the San Jacinto Quadrangle south of San Gorgonio Pass, California. Notes on Mining Activities in Inyo and Mono Counties in July, 1931-----Price $0.40, sales tax $0.01	.41

REPORTS—Continued

Asterisks (**) indicate the publication is out of print.

	Price (including postage and sales tax)
Chapters of Twenty-eighth Report of the State Mineralogist, 'Mining in California,' Walter W. Bradley. Published quarterly:	
January, 1932, Economic Mineral Deposits of the San Jacinto Quadrangle. Geology and Physical Properties of Building Stone from Carmel Valley. Contributions to the Study of Sediments. Sediments of Monterey Bay. Sanbornite____Price $0.40, sales tax $0.01	$0.41
**April, 1932. Elementary Placer Mining Methods and Gold Saving Devices. The Pan, Rocker and Sluice Box. Prospecting for Vein Deposits. Bibliography of Placer Mining____	----
**Abstract from April quarterly: Elementary Placer Mining Methods and Gold Saving Devices. Types of Deposits, Simple Equipment. Special Machines. Dry Washing. Black Sand Treatment. Marketing of Products. Placer Mining Areas. Laws. Prospecting for Quartz Veins. Bibliography (mimeographed)	
**July-October, (Ventura.) Report accompanying Geologic Map of Northern Sierra Nevada. Fossil Plants in Auriferous Gravels of the Sierra Nevada. Glacial and Associated Stream Deposits of the Sierra Nevada. Jurassic and Cretaceous Divisions in the Knoxville-Shasta Succession of California. Geology of a Part of the Panamint Range. Economic Report of a Part of the Panamint Range. Acquiring Mining Claims Through Tax Title. The Biennial Report of State Mineralogist____	----
Chapters of Report XXIX, 1933 (quarterly): title 'California Journal of Mines and Geology,' containing the following:	
January-April. Gold Deposits of the Redding and Weaverville Quadrangles. Geologic Formations of the Redding-Weaverville District, Northern California. Geology of Portions of Del Norte and Siskiyou Counties. Applications of Geology to Civil Engineering. The Lakes of California. Discovery of Piedmontite in the Sierra Nevada. Tracing 'Buried River' Channel Deposits by Geomagnetic Methods. Geologic Map of Redding-Weaverville District, showing gold mines and prospects. Geologic map showing various mines and prospects of part of Del Norte and Siskiyou Counties____Price $1.00, sales tax $0.03	1.03
July-October. Gold Resources of Kern County. Limestone Deposits of the San Francisco Region. Limestone Weathering and Plant Associations of the San Francisco Region. Booming, Death Valley National Monument, California. Placer Mining Districts, Senate Bill 480. Navigable Waters, Assembly Bill 1543____Price $1.00, sales tax $0.03	1.03
Chapters of Report XXX, 1934 (quarterly); titled 'California Journal of Mines and Geology,' containing the following:	
January. Resurrection of Early Surfaces in the Sierra Nevada. Geology and Mineral Resources of Northeastern Madera County. Geology and Mineral Deposits of Laurel and Convict Basins, Southwestern Mono County. Notes on Sampling as Applied to Gold Quartz Deposits____ Price $0.60, sales tax $0.02	.62
April-July. Elementary Placer Mining in California and Notes on the Milling of Gold Ores____Price $1.00, sales tax $0.03	1.03
October. Current Mining Developments in Northern California. Current Mining Activity in Southern California. Geology and Mineral Resources of the Julian District, San Diego County. Geology and Mineral Resources of Elizabeth Lake Quadrangle. Dry Placers of Northern Mojave Desert. Biennial Report of State Mineralogist. Assessment Work Within Withdrawn Areas____Price $0.60, sales tax $0.02	.62
Chapters of Report XXXI, 1935 (quarterly): titled 'California Journal of Mines and Geology,' containing the following:	
January. Review of Gold Mining in East-Central California. 1934. Current Mining Activities in the San Francisco District with Special Reference to Gold. Geological Investigation of the Clays of Riverside and Orange Counties, Southern California. Information regarding Mining Loans by the Reconstruction Finance Corporation____ Price $0.60, sales tax $0.02	.62

REPORTS—Continued

Asterisks (**) indicate the publication is out of print. Price (including postage and sales tax)

April. A Geologic Section Across the Southern Peninsular Range of California. New Technique Applicable to the Study of Placers. Grubstake Permits___Price $0.60, sales tax $0.02 $0.62

July. Mines and Mineral Resources of Siskiyou County (with map). Dams for Hydraulic Mining Debris. Leasing System as Applied to Metal Mining. Mine Financing in California. New Laws Make Radical Change in Mining Rights___Price $0.60, sales tax $0.02 .62

October. Mines and Mineral Resources of San Luis Obispo County. Mineral Resources of Portions of Monterey and Kings Counties. Mining Activity at Soledad Mountain and Middle Buttes—Mojave District, Kern County. Geology of a Portion of the Perris Block, Southern California. Mineral Resources of a Portion of the Perris Block, Riverside County___Price $0.60, sales tax $0.02 .62

Chapters of Report XXXII, 1936 (quarterly): titled 'California Journal of Mines and Geology,' containing the following:

January. Gold Mines of Placer County, including Drag-line Dredges. Geologic Report on Borax Lake, California__Price $0.60, sales tax $0.02 .62

April. Geology, Mining and Processing of Diatomite at Lompoc, Santa Barbara County. Essentials in Developing and Financing a Prospect into a Mine. Gold-bearing Veins of Meadow Lake District, Nevada County. Semi-Precious Gem Stone Collection in Division Museum___ Price $0.60, sales tax $0.02 .62

July. Mines and Mineral Resources of Calaveras County. Mining in California by Power Shovel. Assessment Work on Mining Claims Within Withdrawn Areas. Joshua Tree National Monument. Cost of Producing Quicksilver at a California Mine in 1931-1932. The Age of Mineral Utilization___Price $0.60, sales tax $0.02 .62

October. Mineral Resources of Lassen and Modoc Counties. Mechanics of Lone Mountain Landslides, San Francisco. Biennial Report of the State Mineralogist, Properties and Industrial Applications of Opaline Silica___Price $0.60, sales tax $0.02 .62

Chapters of Report XXXIII, 1937 (quarterly): titled 'California Journal of Mines and Geology,' containing the following:

January. Source Data of the Geologic Map of California, January, 1937. The Geology of Quicksilver Ore Deposits. Prospecting for Lode Gold__ Price $0.60, sales tax $0.02 .62

April. Mineral Resources of Plumas County (with Geologic Map). List of preferred mineral names. New Placer Mining Debris Law___ Price $0.60, sales tax $0.02 .62

July. Mineral Resources of Los Angeles County (with map showing principal Mines and Oil Fields). Geology and mineral deposits of the Western San Gabriel Mountains, Los Angeles County___ Price $0.60, sales tax $0.02 .62

October. Mineral Resources of the Resting Springs Region, Inyo County. Paleozoic Section in the Nopah and Resting Springs Mountains, Inyo County, California. Native Arsenic from Grass Valley, California___ Price $0.60, sales tax $0.02 .62

Chapters of Report XXXIV, 1938 (quarterly): titled 'California Journal of Mines and Geology,' containing the following:

**January. Mineral Development and Mining Activity in Southern California during the year 1937. Doing Something About Earthquakes. Gold and Petroleum in California. Gem Minerals of California, Lapidary Art ___ ----

April. Gold Dredging in Shasta, Siskiyou and Trinity Counties; Geology of the Central Santa Monica Mountains; Marketing Mica___ Price $0.60, sales tax $0.02 .62

July. El Dorado County, Mineral High-Lights of California; Strategic Minerals of California; Cyanide Treatment of Gossan at Mountain Copper Co.; Submarine Canyons off the California Coast___ Price $0.60, sales tax $0.02 .62

REPORTS—Continued

Asterisks (**) indicate the publication is out of print. Price (including postage and sales tax)

October, Inyo County, Biennial Report of State Mineralogist, Sulphur Deposits of Inyo County, Geology of the Darwin-Lead Mining District Price $0.60, sales tax $0.02 $0.62

Chapters of Report XXXV, 1939 (quarterly) titled "California Journal of Mines and Geology," containing the following:

January, San Diego County, Geology and Oil Possibilities of Southwestern San Diego Co.; Prospect for 'Minor Metals' and Nonmetallic Minerals; The Right to Mine Price $0.60, sales tax $0.02 .62

April, Shasta County, Public's Interest in Mine Taxation Price $0.60, sales tax $0.02 .62

July, Tertiary Formations of Northern Sacramento Valley, California; Geology and Oil Possibilities of Caliente Range, Cuyama Valley and Carrizo Plain, California; Bibliography of the Geology and Mineral Resources of California for the year 1937; the Giant Goose Lake Meteorite from Modoc County, California Price $0.60, sales tax $0.02 .62

**October, Quicksilver Resources of California; Sulphate Minerals of the Leviathan Sulphur Mine, Alpine County, California

Reprint from above, Quicksilver Resources of California Price $0.50, sales tax $0.01 .51

Chapter of Report XXXVI, 1940 (quarterly) titled "California Journal of Mines and Geology," containing the following:

January Current Mining Activity in Southern California; Notes on Beryl with a Qualitative Analysis for Beryllium; Strategic Minerals Investigations Procedure followed by the U. S. Bureau of Mines Price $0.60, sales tax $0.02 .62

April, Mineral Resources of Mono County; General Geology and Ores of the Blind Spring Hill Mining District, Mono County, California; Short Report on the Geological Formations Encountered in Driving the Mono Craters Tunnel; Methods and Costs of Mining and Concentrating Chromite Price $0.60, sales tax $0.02 .62

July, Economic Mineral Deposits of the Newberry and Ord Mountains, San Bernardino County; Geology of the Newberry and Ord Mountains, San Bernardino County, California; Notes on the Geology of a Portion of the Calico Mountains, San Bernardino County, California; Study of Chrome Process Aided by Martin Dennis Company Price $0.60, sales tax $0.02 .62

October, Mineral Resources of the Kernville Quadrangle; Strategic Problems of the Mineral Industry in California; Descriptive Geology of the Kernville Quadrangle, California; Biennial Report of the State Mineralogist; Strategic Tax Exemption; Federal Loans for Strategic Minerals Price $0.60, sales tax $0.02 .62

Chapters of Report XXXVII, 1941 (quarterly) titled "California Journal of Mines and Geology," containing the following:

January, Mineral Resources of Trinity County; Strategic Minerals Procurement; Geologic Investigation of the Chromite Deposits of California; United States Supreme Court Renders Far-reaching Decision on Power Permits on "Navigable" Streams; Securities and Exchange Commission Price $0.60, sales tax $0.02 .62

April, Tungsten Resources of California; Geological Progress of State Division of Mines; California Earthquakes of Mission Period, 1769-1838 Price $0.60, sales tax $0.02 .62

July, (Nevada County Report and Maps) Mines and Mineral Resources of Nevada County; Price of Gold Price $0.60, sales tax $0.02 .62

October, (Humboldt County) Mineral Resources of Humboldt County; Recent Developments in the Tungsten Resources of California; Tin in California Price $0.60, sales tax $0.02 .62

Chapters of Report XXXVIII, 1942 (quarterly) titled "California Journal of Mines and Geology," containing the following:

January, Mines and Mineral Resources of Sierra County; Chromium Price $0.60, sales tax $0.02 .62

REPORTS—Continued

Asterisks (**) indicate the publication is out of print. | Price (including postage and sales tax)

April, Mineral Resources of Imperial County (report and map); Geology and Mineral Deposits of the Cargo Muchacho Mountains, Imperial County (map and report); Imperial Carbon Dioxide Gas Field; Legendary "White Metal" and Its "Ore"; Mine Assessment Work Suspended on Claims Within Withdrawn Areas__________ Price $0.60, sales tax $0.02 $0.62

July-October, Tungsten. Tabulated list of deposits; Economic Mineral Map No. 4—Tungsten; Geology of Ghost Canyon Deposit, Madera County; Geology of Welsh Deposit, Madera County; Geology of Confidence Mining District Deposits, Tuolumne County; Contact-Metamorphic Rocks of Twin Lakes Region, Fresno County; Coso Hot Springs Geology; Biennial Report of State Mineralogist__________ Price $1.20, sales tax $0.03 1.23

Chapters of Report XXXIX, 1943 (quarterly) titled "California Journal of Mines and Geology" containing the following:

January, Mines and Mineral Resources of Santa Cruz County (report and map); Organization and Service of the Division of Mines; Recent Activity in the Strategic Minerals in the San Francisco, Los Angeles, Sacramento, and Redding Field Districts; Department of Interior Information Service__________Price $0.60, sales tax $0.02 .62

April, Manganese Discovery in San Mateo County; Current Mining Activity in Southern California; Current Notes on Activity in Strategic Minerals, Sacramento Field District; Clerbus-Mae Tungsten Prospect, Trinity County; Mylonites in Eastern San Gabriel Mountains; Geology of Sierra Nevada Northeast of Visalia, Tulare County; Tungsten Deposits Northeast of Visalia, Tulare County; Geology of San Benito Quadrangle (report and map)__________Price $0.60, sales tax $0.02 .62

July, Carbon Dioxide Gas in Mendocino and Northern Sonoma Counties; Current notes on Activity in Strategic Minerals, Redding and Sacramento Field Districts; Crestmore Minerals; The Isometrograph as Developed and Used at New Idria Quicksilver Mine; Notes relating to Sutter (Marysville) Buttes Gas Field; Sillimanite Group of Minerals; New Federal and State Legislation Affecting Mining__________ Price $0.60, sales tax $0.02 .62

October, Mines and Mineral Resources of San Bernardino County (report and map); Current Notes on Activity in Strategic Minerals, Sacramento Field District__________Price $0.60, sales tax $0.02 .62

Subscription, $2.00 postpaid in advance

BULLETINS

**Bulletin No. 1. Description of Some Desiccated Human Remains, by Winslow Anderson. 1888, 41 pp., 6 illustrations__________ ----

**Bulletin No. 2. Methods of Mine Timbering, by W. H. Storms. 1894, 58 pp., 75 illustrations__________ ----

**Bulletin No. 3. Gas and Petroleum Yielding Formations of Central Valley of California, by W. L. Watts. 1894, 100 pp., 13 illustrations, 4 maps __________ ----

**Bulletin No. 4. Catalogue of California Fossils, by J. G. Cooper. 1894, 73 pp., 67 illustrations. (Part I was published in the Seventh Annual Report of the State Mineralogist, 1887)__________ ----

**Bulletin No. 5. The Cyanide Process, 1894, by Dr. A. Scheidel. 140 pp., 46 illustrations __________ ----

**Bulletin No. 6. California Gold Mill Practices, 1895, by E. B. Preston. 85 pp., 46 illustrations__________ ----

**Bulletin No. 7. Mineral Production of California, by Counties, for the year 1894, by Charles G. Yale. Tabulated sheet__________ ----

**Bulletin No. 8. Mineral Production of California, by Counties, for the year 1895, by Charles G. Yale. Tabulated sheet__________ ----

BULLETINS—Continued

Asterisks (**) indicate the publication is out of print.

	Price (including postage and sales tax)
**Bulletin No. 9. Mine Drainage, Pumps, etc., by Hans C. Behr. 1896, 210 pp., 206 illustrations	----
**Bulletin No. 10. A Bibliography Relating to the Geology, Paleontology and Mineral Resources of California, by Anthony W. Vogdes. 1896, 121 pp.	----
**Bulletin No. 11. Oil and Gas Yielding Formations of Los Angeles, Ventura and Santa Barbara Counties, by W. L. Watts. 1897, 94 pp., 6 maps, 31 illustrations	----
**Bulletin No. 12. Mineral Production of California, by Counties, for 1896, by Charles G. Yale. Tabulated sheet	----
**Bulletin No. 13. Mineral Production of California, by Counties, for 1897, by Charles G. Yale. Tabulated sheet	----
**Bulletin No. 14. Mineral Production of California, by Counties, for 1898, by Charles G. Yale	----
**Bulletin No. 15. Map of Oil City Fields, Fresno County, by John H. Means, 1899	----
**Bulletin No. 16. The genesis of Petroleum and Asphaltum in California, by A. S. Cooper. 1899, 39 pp., 29 illustrations	----
**Bulletin No. 17. Mineral Production of California, by Counties, for 1899, by Charles G. Yale. Tabulated sheet	----
**Bulletin No. 18. Mother Lode Region of California, by W. H. Storms, 1900, 154 pp., 49 illustrations	----
**Bulletin No. 19. Oil and Gas Yielding Formations of California, by W. L. Watts. 1900, 236 pp., 60 illustrations, 8 maps	----
**Bulletin No. 20. Synopsis of General Report of State Mining Bureau, by W. L. Watts. 1901, 21 pp. This bulletin contains a brief statement of the progress of the mineral industry in California for the four years ending December, 1899	----
**Bulletin No. 21. Mineral Production of California by Counties, by Charles G. Yale. 1900. Tabulated sheet	----
**Bulletin No. 22. Mineral Production of California for Fourteen Years, by Charles G. Yale. 1900. Tabulated sheet	----
Bulletin No. 23. The Copper Resources of California, by P. C. DuBois, F. M. Anderson, J. H. Tibbits and G. A. Tweedy. 1902, 282 pp., 69 illustrations, 9 maps. Price $0.75, sales tax $0.02	$0.77
**Bulletin No. 24. The Saline Deposits of California, by G. E. Bailey. 1902, 216 pp., 99 illustrations, 5 maps	----
**Bulletin No. 25. Mineral Production of California, by Counties, for 1901, by Charles G. Yale. Tabulated sheet	----
**Bulletin No. 26. Mineral Production of California for the Past Fifteen Years, by Charles G. Yale. 1902. Tabulated sheet	----
**Bulletin No. 27. The Quicksilver Resources of California, by William Forstner. 1903, 273 pp., 144 illustrations, 8 maps	----
**Bulletin No. 28. Mineral Production of California for 1902, by Charles G. Yale. Tabulated sheet	----
**Bulletin No. 29. Mineral Production of California for Sixteen Years, by Charles G. Yale. 1903. Tabulated sheet	----
**Bulletin No. 30. Bibliography Relating to the Geology, Palentology and Mineral Resources of California, by A. W. Vogdes. 1903, 290 pp.	----
**Bulletin No. 31. Chemical Analyses of California Petroleum, by H. N. Cooper. 1904. Tabulated sheet	------
**Bulletin No. 32. Production and Use of Petroleum in California by Paul W. Prutzman. 1904, 230 pp., 116 illustrations, 14 maps	----
**Bulletin No. 33. Mineral Production of California, by Counties, for 1903, by Charles G. Yale. Tabulated sheet	----
**Bulletin No. 34. Mineral Production of California for Seventeen Years, by Charles G. Yale. 1904. Tabulated sheet	----
**Bulletin No. 35. Mines and Minerals of California, by Charles G. Yale, 1904, 55 pp., 20 county maps. Relief maps of California	----

BULLETINS—Continued

Asterisks (**) indicate the publication is out of print.

	Price (including postage and sales tax)
**Bulletin No. 36. Gold Dredging in California, by J. E. Doolittle. 1905. 120 pp., 60 illustrations, 3 maps	----
**Bulletin No. 37. Gems, Jewelers' Materials, and Ornamental Stones of California, by George F. Kunz. 1905, 168 pp., 54 illustrations	----
**Bulletin No. 38. Structural and Industrial Materials of California, by Wm. Forstner, T. C. Hopkins, C. Naramore and L. H. Eddy. 1906, 412 pp., 150 illustrations, 1 map	----
**Bulletin No. 39. Mineral Production of California, by Counties, for 1904, by Charles G. Yale. Tabulated sheet	----
**Bulletin No. 40. Mineral Production of California for Eighteen Years, by Charles G. Yale. 1905. Tabulated sheet	----
**Bulletin No. 41. Mines and Minerals of California for 1904, by Charles G. Yale. 1905, 54 pp., 20 county maps	----
**Bulletin No. 42. Mineral Production of California, by Counties, 1905, by Charles G. Yale. Tabulated sheet	----
**Bulletin No. 43. Mineral Production of California for Nineteen Years, by Charles G. Yale. Tabulated sheet	----
**Bulletin No. 44. California Mines and Minerals for 1905, by Charles G. Yale. 1907, 31 pp., 20 county maps	----
**Bulletin No. 45. Auriferous Black Sands of California, by J. A. Edman, 1907. 10 pp.	----
**Bulletin No. 46. General Index of Publications of the California State Mining Bureau, by Charles G. Yale. 1907, 54 pp.	----
**Bulletin No. 47. Mineral Production of California, by Counties, 1906, by Charles G. Yale. Tabulated sheet	----
**Bulletin No. 48. MineralProduction of California for Twenty Years, by Charles G. Yale. 1906	----
**Bulletin No. 49. Mines and Minerals of California for 1906, by Charles G. Yale. 34 pp.	----
Bulletin No. 50. The Copper Resources of California, 1908, by A. Hausmann, J. Kruttschnitt, Jr., W. E. Thorn and J. A. Edman, 366 pp., 74 illustrations. (Revised edition) Price $1.50, sales tax $0.04	$1.54
**Bulletin No. 51. Mineral Production of California, by Counties, 1907, by D. H. Walker. Tabulated sheet	----
**Bulletin No. 52. Mineral Production of California for Twenty-one Years, by D. H. Walker. 1907. Tabulated sheet	----
**Bulletin No. 53. Mineral Production of California for 1907, with County Maps, by D. H. Walker, 62 pp.	----
**Bulletin No. 54. Mineral Production of California, by Counties, by D. H. Walker. 1908. Tabulated sheet	----
**Bulletin No. 55. Mineral Production of California for Twenty-two Years, by D. H. Walker. 1908. Tabulated sheet	----
**Bulletin No. 56. Mineral Production for 1908, with County Maps and Mining Laws of California, by D. H. Walker, 78 pp.	----
**Bulletin No. 57. Gold Dredging in California, by W. B. Winston and Chas. Janin. 1910, 312 pp., 239 illustrations, 10 maps	----
**Bulletin No. 58. Mineral Production of California, by Counties, by D. H. Walker. 1909. Tabulated sheet	----
**Bulletin No. 59. Mineral Production of California for Twenty-three Years, by D. H. Walker. 1900. Tabulated sheet	----
**Bulletin No. 60. Mineral Production for 1909, with County Maps and Mining Laws of California, by D. H. Walker. 94 pp.	----
**Bulletin No. 61. Mineral Production of California, by Counties, for 1910, by D. H. Walker. Tabulated sheet	----
**Bulletin No. 62. Mineral Production of California for Twenty-four Years, by D. H. Walker. 1910. Tabulated sheet	----
**Bulletin No. 63. Petroleum in Southern California, by P. W. Prutzman. 1912, 430 pp., 41 illustrations, 6 maps	----
**Bulletin No. 64. Mineral Production for 1911, by E. S. Boalich. 49 pp.	----
**Bulletin No. 65. Mineral Production for 1912, by E. S. Boalich. 64 pp.	----

BULLETINS—Continued

Asterisks (**) indicate the publication is out of print. Price (including postage and sales tax)

**Bulletin No. 66. Mining Laws of the United States and California. 1914, 89 pp.	----
**Bulletin No. 67. Minerals of California, by Arthur S. Eakle. 1914, 226 pp.	----
**Bulletin No. 68. Mineral Production for 1913, with County Maps and Mining Laws, by E. S. Boalich. 160 pp.	----
**Bulletin No. 69. Petroleum Industry of California, with Folio of Maps (18 by 22), by R. P. McLaughlin and C. A. Waring. 1914, 519 pp., 13 illustrations, 83 figs. [18 plates in accompanying folio.]	----
**Bulletin No. 70. Mineral Production for 1914, with County Maps and Mining Laws. 184 pp.	----
**Bulletin No. 71. Mineral Production for 1915, with County Maps and Mining Laws, by Walter W. Bradley, 193 pp. 4 illustrations	----
**Bulletin No. 72. The Geoolgic Formations of California, by James Perrin Smith. 1916, 47 pp.	----
**Reconnaissance Geologic Map (of which Bulletin 72 is explanatory), in 23 colors. Scale: 1 inch = 12 miles. Mounted	----
**Bulletin No. 73. First Annual Report of the State Oil and Gas Supervisor of California for the fiscal year 1915-16, by R. P. McLaughlin. 278 pp., 26 illustrations	----
**Bulletin No. 74. Mineral Production of California in 1916, with County Maps, by Walter W. Bradley. 179 pp., 12 illustrations	----
**Bulletin No. 75. United States and California Mining Laws. 1917, 115 pp., paper	----
Bulletin No. 76. Manganese and Chromium in California, by Walter W. Bradley, Emile Huguenin, C. A. Logan, W. B. Tucker and C. A. Waring. 1918, 248 pp., 51 illustrations, 5 maps, paper Price \$0.75, sales tax \$0.02	\$0.77
Bulletin No. 77. Catalogue of Publications of California State Mining Bureau, 1880-1917, by E. S. Boalich. 44 pp., paper	Free
**Bulletin No. 78. Quicksilver Resources of California, with a Section on Metallurgy and Ore-Dressing, by Walter W. Bradley. 1919, 389 pp., 77 photographs and 42 plates (colored and line cuts), cloth	----
Bulletin No. 79. Magnesite in California, by Walter W. Bradley. 1925, 147 pp., 62 photographs, 11 line cuts and maps, cloth Price \$1.25, sales tax \$0.03	1.28
†Bulletin No. 80. Tungsten. Molybdenum and Vanadium in California. (Not issued—See Apr. 1941 Chap. Report XXXVII.)	
†Bulletin No. 81. Foothill Copper Belt of California. (Not issued.)	
**Bulletin No. 82. Second Annual Report of the State Oil and Gas Supervisor, for the Fiscal Year 1916-1917, by R. P. McLaughlin. 1918, 412 pp., 31 illustrations, cloth	----
**Bulletin No. 83. California Mineral Production for 1917, with County Maps, by Walter W. Bradley. 179 pp., paper	----
**Bulletin No. 84. Third Annual Report of the State Oil and Gas Supervisor, for the Fiscal Year 1917-1918, by R. P. McLaughlin. 1918, 617 pp., 28 illustrations, cloth	----
**Bulletin No. 85. Platinum and Allied Metals in California, by C. A. Logan, 1919. 10 photographs, 4 plates, 120 pp., paper	----
**Bulletin No. 86. California Mineral Production for 1918, with County Maps, by Walter W. Bradley. 1919, 212 pp., paper	----
**Bulletin No. 87. Commercial Minerals of California, with notes on their uses, distribution, properties, ores, field tests and preparation for market, by W. O. Castello. 1920, 124 pp., paper	----
**Bulletin No. 88. California Mineral Production for 1919, with County Maps, by Walter W. Bradley. 1920, 204 pp., paper	----
**Bulletin No. 89. Petroleum Resources of California, with Special Reference to Unproved Areas, by Lawrence Vander Leck. 1921, 12 figures, 6 photographs, 6 maps in pocket, 186 pp., cloth	----

† Not issued.

BULLETINS—Continued

Asterisks (**) indicate the publication is out of print.	Price (including postage and sales tax)
**Bulletin No. 90. California Mineral Production for 1920, with County Maps, by Walter W. Bradley. 1921, 218 pp., paper	----
**Bulletin No. 91. Minerals of California, by Arthur S. Eakle. 1923, 328 pp., cloth	----
**Bulletin No. 92. Gold Placers of California, by Charles S. Haley. 1923, 167 pp., 36 photographs and 7 plates (colored and line cuts, also geological map), cloth	----
**Bulletin No. 93. California Mineral Production for 1922, by Walter W. Bradley. 1923, 188 pp., paper	----
**Bulletin No. 94. California Mineral Production for 1923, by Walter W. Bradley. 1924, 162 pp., paper	----
**Bulletin No. 95. Geology and Ore Deposits of the Randsburg Qaudrangle, by Carlton D. Hulin. 1925, 152 pp., 49 photographs, 13 line cuts, 1 colored geologic map, cloth	----
**Bulletin No. 96. California Mineral Production for 1924, by Walter W. Bradley. 1925, 173 pp., paper	----
**Bulletin No. 97. California Mineral Production for 1925, by Walter W. Bradley. 1926, 172 pp., paper	----
Bulletin No. 98. American Mining Law, by A. H. Ricketts, 1931, 811 pp., flexible leather — Price $2.50, sales tax $0.06	$2.56
Bulletin No. 99. Clay Resources and Ceramic Industry of California, by Waldemar Fenn Deitrich. 1928, 383 pp., 70 photographs, 12 line cuts including maps, cloth — Price $2.00, sales tax $0.05	2.05
**Bulletin No. 100. California Mineral Production for 1926, by Walter W. Bradley, 1927, 174 pp., paper	----
**Bulletin No. 101. California Mineral Production for 1927, by Henry H. Symons. 1928, 311 pp., paper	----
**Bulletin No. 102. California Mineral Production for 1928, by Henry H. Symons. 1929, 210 pp., paper	----
Bulletin No. 103. California Mineral Production for 1929, by Henry H. Symons. 1930, 231 pp., paper	----
Bulletin No. 104. Bibliography of the Geology and Mineral Resources of California, to the end of 1930, by Solon Shedd — Price $2.50, sales tax $0.06	2.56
Bulletin No. 105. Mineral Production in California for 1930 and Directory of Producers, by Henry H. Symons. 1931	
Bulletin No. 106. Superseded. (See Bulletin No. 120.)	
Bulletin No. 107. Mineral Production in California for 1931 and Directory of Producers, by Henry H. Symons. 1932	
Bulletin No. 108. Mother Lode Gold Belt of California, by Clarence A. Logan, 1934, 240 pp., with geologic and claim maps, cloth — Price $2.25, sales tax $0.06	2.31
Bulletin No. 109. California Mineral Production and Directory of Mineral Producers for 1932, by Henry H. Symons, 200 pp., paper	----
Bulletin No. 110. California Mineral Production and Director of Mineral Producers for 1933, by Henry H. Symons, 214 pp., paper	----
Bulletin No. 111. California Mineral Production and Directory of Mineral Producers for 1934, by Henry H. Symons, 334 pp., paper	----
Bulletin No. 112. California Mineral Production and Directory of Mineral Producers for 1935, by Henry H. Symons, 205 pp., paper	----
Bulletin No. 113. Minerals of California, by Adolf Pabst, 1938	----
Price $1.75, sales tax $0.04	1.79
Bulletin No. 114. California Mineral Production and Directory of Mineral Producers for 1936, by Henry H. Symons, 119 pp., paper	----
Bulletin No. 115. Bibliography of Geology and Mineral Resources of California, 1931 to 1936, by Solon Shedd, Supplementing Bulletin No. 104 — Price $1.25, sales tax $0.03	1.28
Bulletin No. 116. California Mineral Production and Directory of Mineral Producers for 1937, by Henry H. Symons. 1938	
Bulletin No. 117. California Mineral Production and Director of Mineral Producers for 1938, by Henry H. Symons. 1939	

BULLETINS—Continued

Asterisks (**) indicate the publication is out of print. Price (including postage and sales tax)

Bulletin No. 118
Geologic Formations and Economic Development of the Oil and Gas Fields of California, by O. P. Jenkins and others
Part One—Development of the Industry, 1940
Part Two—Geology of California and the Occurrence of Oil and Gas, 1941
Part Three—Descriptions of Individual Oil and Gas Fields, 1943
Part Four—Glossaries, Bibliography, and Index, 1943, paper covered separates____Four parts $4.00, sales tax $0.10 $4.10
Complete in one volume (cloth bound)____Price $6.00, sales tax $0.15 6.15

**Bulletin No. 119. Mineral Production of California for 1939, and Directory of Producers, by Henry H. Symons. 1940____ ----

**Bulletin No. 120. Manner of Locating and Holding Mineral Claims in California (with forms), by A. H. Ricketts (revised 1941) Superseded (See Bulletin 127)____ ----

Bulletin No. 121. Mineral Production of California for 1940, and Directory of Producers, by Henry H. Symons. 1941____ Free

Bulletin No. 122. Mineral Production of California for 1941; Directory of Producers and Tables of Total Recorded Production by Counties, by Henry H. Symons, 377 pp., paper____ Free

Bulletin No. 123. American Mining Law, by A. H. Ricketts, 1943, 1008 pp., cloth ____Price $5.00, sales tax $0.13 5.13

Bulletin No. 124. Commercial Minerals of California, by George L. Gary. A loose-leaf mimeographed bulletin arranged so that it may be revised and supplemented. 1942____Price $1.00, sales tax $0.03 1.03
With binder ____Price $1.30, sales tax $0.04 1.34
Revised papers mailed upon receipt of postage

Bulletin No. 125. Manganese in California____Price $3.00, sales tax $0.08 3.08

Bulletin No. 126. Mineral Production of California for 1942, and Directory of Producers, by Henry H. Symons, 1943____Price $0.75, sales tax $0.02 .77

Bulletin No. 127. Manner of Locating and Holding Mineral Claims in California (with forms), by A. H. Ricketts (revised 1944)____Price $0.25, sales tax $0.01 .26

PRELIMINARY REPORTS

**Preliminary Report No. 1. Notes on Damage by Water in California Oil Fields, December, 1913. By R. P. McLaughlin, 4 pp.____ ----

Preliminary Report No. 2. Notes on Damage by Water in California Oil Fields, March, 1914. By R. P. McLaughlin, 4 pp.____ Free

Preliminary Report No. 3. Manganese and Chromium, 1917. By E. S. Boalich. 32 pp.____ Free

**Preliminary Report No. 4. Tungsten, Molybdenum and Vanadium. By E. S. Boalich and W. O. Castello, 1918. 34 pp. Paper____ ----

**Preliminary Report No. 5. Antimony, Graphite, Nickel, Potash, Strontium and Tin. By E. S. Boalich and W. O. Castello, 1918. 44 pp. Paper ----

Preliminary Report No. 6. A Review of Mining in California During 1919. By Fletcher Hamilton, 1920. 43 pp. Paper____ Free

**Preliminary Report No. 7. The Clay Industry in California. By E. S. Boalich, W. O. Castello, E. Huguenin, C. A. Logan, and W. B. Tucker, 1920. 102 pp. 24 illustrations. Paper____ ----

Preliminary Report No. 8. A Review of Mining in California During 1921, with Notes on the Outlook for 1922. By Fletcher Hamilton, 1922. 68 pp. Paper____ Free

MINERAL ABSTRACTS

Antimony, 26 pp.____Price $0.25, sales tax $0.01 .26
Iron, 52 pp.____Price $0.35, sales tax $0.01 .36
Pumice and Volcanic Ash, 50 pp.____Price $0.35, sales tax $0.01 .36
Sulphur, 23 pp.____Price $0.25, sales tax $0.01 .26
**Tungsten, 33 pp.____ ----

MISCELLANEOUS PUBLICATIONS

Asterisks (**) indicate the publication is out of print.

	Price (including postage and sales tax)
**First Annual Catalogue of the State Museum of California, being the collection made by the State Mining Bureau during the year ending April 16, 1881. 350 pp.	----
**Catalogue of books, maps, lithographs, photographs, etc., in the library of the State Mining Bureau at San Francisco, May 15, 1884. 19 pp.	----
**Catalogue of the State Museum of California, Volume II, being the collection made by the State Mining Bureau from April 16, 1881, to May 5, 1884. 220 pp.	----
**Catalogue of the State Museum of California, Volume III, being the collection made by the State Mining Bureau from May 15, 1884, to March 31, 1887. 195 pp.	----
Quicksilver Resources of California ---- Price $0.50, sales tax $0.01	$0.51
**Catalogue of the State Museum of California, Volume IV, being the collection made by the State Mining Bureau from March 30, 1887, to August 20, 1890. 261 pp.	----
**Lakes of California	----
**Drift Mining in California (Reprint)	----
**Catalogue of the Library of the California State Mining Bureau, September 1, 1892. 149 pp.	----
**Catalogue of West North American and Many Foreign Shells with Their Geographical Ranges, by J. G. Cooper. Printed for the State Mining Bureau, April, 1894	----
**Report of the Board of Trustees for the four years ending September, 1900. 15 pp. Paper	----
Reconnaissance of the Colorado Desert Mining District. By Stephen Bowers, 1901. 19 pp. 2 illustrations. Paper	Free
Commercial Mineral Notes. A monthly mimeographed sheet, beginning April, 1923 ---- (by mail 25¢ annually)	Free

Write for latest revised price list.

MAPS

Register of Mines with Maps

**Register of Mines, with Map, Amador County	----
**Register of Mines, with Map, Butte County	----
**Register of Mines, with Map, Calaveras County	----
**Register of Mines, with Map, El Dorado County	----
**Register of Mines, with Map, Inyo County	----
**Register of Mines, with Map, Kern County	----
**Register of Mines, with Map, Lake County	----
**Register of Mines, with Map, Mariposa County	----
**Register of Mines, with Map, Nevada County	----
**Register of Mines, with Map, Placer County	----
**Register of Mines, with Map, Plumas County	----
**Register of Mines, with Map, San Bernardino County	----
**Register of Mines, with Map, San Diego County	----
Register of Mines, with Map, Santa Barbara County (1906) ---- Price $0.15, sales tax $0.01	.16
**Register of Mines, with Map, Shasta County	----
**Register of Mines, with Map, Sierra County	----
**Register of Mines, with Map, Siskiyou County	----
**Register of Mines, with Map, Trinity County	----
**Register of Mines, with Map, Tuolumne County	----
Register of Mines, with Map, Yuba County (1905) ---- Price $0.15, sales tax $0.01	.16
**Register of Oil Wells, with Map, Los Angeles City (1906)	----

Other Maps

Asterisks (**) indicate the publication is out of print.

	Price (including postage and sales tax)
**Map of California, Showing Mineral Deposits (50x60 in.)	----
**Map of Forest Reserves in California	----
**Mineral and Relief Map of California	----
**Map of El Dorado County, Showing Boundaries, National Forests	----
**Map of Madera County, Showing Boundaries, National Forests	----
**Map of Placer County, Showing Boundaries, National Forests	----
**Map of Shasta County, Showing Boundaries, National Forests	----
**Map of Sierra County, Showing Boundaries, National Forests	----
**Map of Siskiyou County, Showing Boundaries, National Forests	----
**Map of Tuolumne County, Showing Boundaries, National Forests	----
Map of Mother Lode Region, Geologic	$0.10
**Map of Desert Region of Southern California	----
Map of Minaret District, Madera County	.10
Map of Copper Deposits in California	Free
**Map of Calaveras County	----
**Map of Plumas County	----
**Map of Trinity County	----
**Map of Tuolumne County	----
**Geographical Map of Inyo County. Scale 1 inch equals 4 miles	----
**Map of California accompanying Bulletin No. 89, showing generalized classification of land with regard to oil possibilities. Map only, without Bulletin	----
**Geologic Map of California, 1916. Scale 1 inch equals 12 miles. Shows railroads, highways, post offices and other towns. Geological details lithographed in 23 colors. Mounted	----
**Unmounted	----
Geologic Map of California, 1938. Scale 8 miles per inch. Lithographed in 80 distinguishing colors and patterns showing geologic units. In 6 sections, each 32 in. x 42 in. Set of 6 sheets, unmounted. Sheets not sold separately — Price $4.00, sales tax $0.10	4.10
**Topographic Map of Sierra Nevada Gold Belt, showing distribution of auriferous gravels, accompanying Bulletin No. 92. In 4 colors	----
Geologic Map of Northern Sierra Nevada, showing Tertiary River Channels and Mother Lode Belt accompanying July-October Chapter of Report XXVIII of the State Mineralogist. (Sold singly) — Price $0.25, sales tax $0.01	.26
Map of Northern California, showing rivers and creeks which produced placer gold in 1932 — Price $0.15, sales tax $0.01	.16
Mother Lode Geologic and claim maps in 5 county sections: El Dorado, Amador, Calaveras, Tuolumne and Mariposa, 5 maps sold separately, each — Price $0.15, sales tax $0.01	.16
Map of Mariposa County, showing principal gold mines — Price $0.15, sales tax $0.01	.16
**Geologic Map of Elizabeth Lake Quadrangle, Los Angeles and Kern Counties (accompanying October Chapter of Report XXX), sold separately	----
Map of Western Portion of Siskiyou County Showing Location of Principal Gold Mines (accompanying July Chapter of Report XXXI), sold separately — Price $0.15, sales tax $0.01	.16
Geologic Map of Redding and Weaverville Quadrangles Showing Location of Gold Mines — Price $0.15, sales tax $0.01	.16
Map of Ancient Channel System, Calaveras County; Map of Ancient Channels Between San Andreas and Mokelumne Hill — Set of 2 — Price $0.25, sales tax $0.01	.26
Minaret District, Madera County	.10
Perris Block Geologic	.10
Plumas County Geologic — Price $0.15, sales tax $0.01	.16
Shasta County — Price $0.15, sales tax $0.01	.16
El Dorado County — Price $0.15, sales tax $0.01	.16
Trinity County, Showing Locations of Principal Mineral Deposits (accompanying Jan. Chapt. of Report XXXVII) — Price $0.15, sales tax $0.01	.16

Other Maps—Continued

Asterisks (**) indicate the publication is out of print.

	Price (including postage and sales tax)
Quicksilver deposits, sold in conjunction with Quicksilver Resources of California (reprint) ---- Price $0.50, sales tax $0.01	$0.51
Nevada County (accompanying July Chapter of Report XXXVII) ---- Price $0.15, sales tax $0.01	.16
Grass Valley and Nevada City District claim map ----	.10
Oil and Gas Fields Map ---- Price $1.00, sales tax $0.03	1.03
Chromite deposits ---- Price $0.60, sales tax $0.02	.62
Tungsten deposits, sold in conjunction with July-October 1942 Chapter of Report XXXVIII ---- Price $0.60, sales tax $0.02	.62
Chart of Commercial Minerals of California ----	Free
Imperial County (accompanying April chapter of Report XXXVIII) ----	.10
Index Map of Economic Minerals and Geomorphic Provinces ----	Free
Inyo County (accompanying Oct. chapter of Report XXXIV) ---- Price $0.15, sales tax $0.01	.16
Kernville Quadrangle (accompanying October chapter of Report XXXVI)	.10
Los Angeles County (accompanying July chapter of Report XXXIII) ---- Price $0.15, sales tax $0.01	.16
Manganese deposits ---- Price $0.60, sales tax $0.02	.62
Mono County (accompanying April chapter of Report XXXVI) ----	.10
San Diego County (accompanying January chapter of Report XXXV) ---- Price $0.15, sales tax $0.01	.16
Santa Cruz County (accompanying January chapter of Report XXXIX) ---- Price $0.15, sales tax $0.01	.16
Geologic Map of Western Santa Monica Mountains ----	.10

OIL AND GAS FIELD MAPS

The following maps are on sale at the State Division of Oil and Gas, Ferry Building, San Francisco, and the various branch offices. The maps are revised as development work advances and ownerships change. Price includes postage.

No.		*Price*
1	Sargent, Santa Clara County ----	$0.75
2	Santa Maria, including Cat Canyon—Los Alamos, Santa Barbara County ----	1.25
3	Santa Maria, including Casmalia and Lompoc, Santa Barbara County ----	1.25
4	Brea Olinda and East Coyote, Los Angeles, Orange Counties ----	1.25
6	Salt Lake—Beverly Hills, Los Angeles County ----	1.25
7	Sunset, including San Emidio, Kern County ----	1.25
8	South Midway, including Buena Vista Hills, Kern County ----	1.25
9	North Midway and McKittrick, Kern and San Luis Obispo Counties ----	1.25
10	South Belridge and McKittrick-Temblor, Kern County ----	1.25
11	Lost Hills and North Belridge, including Antelope Hills, Kern County ----	1.25
12	Devils Den, Kern County ----	1.00
13	Kern River and Kern Front, including portion of Poso Creek Field, Kern County ----	1.00
14	Coalinga, Jacalitos, and East Coalinga Extension, Fresno County ----	1.50
15	Elk Hills, Kern County ----	1.25
16	Ventura-Ojai, Ventura County ----	1.75
17	Santa Paula-Ojai, including South Mountain, Ventura County ----	1.25
18	Sespe-Piru-Simi, including Bardsdale, Ventura County ----	1.50
18a	Newhall, Aliso Canyon, Newhall-Potrero, Del Valle and Oak Canyon, Los Angeles County ----	1.25
19	Arroyo Grande, San Luis Obispo County ----	1.00
20	Long Beach, Los Angeles County ----	1.75
21B	District 5, boundaries of areas including oil fields, Fresno, Kings and Kern Counties ----	1.00
21C	District 4, boundaries of areas including oil fields, Kern, Kings and Tulare Counties ----	1.25

OIL AND GAS FIELD MAPS—Continued

No.	*Price*
22—District 3, boundaries of areas including oil fields, Santa Barbara County	$0.75
23—District 2, boundaries of areas including oil fields, Ventura County	1.00
24—District 1, boundaries of areas including oil fields, Los Angeles and Orange Counties	1.00
26—Huntington Beach, Orange County	1.50
27—Santa Fe Springs, Los Angeles County	1.25
28—Torrance, Los Angeles County	1.25
28a—Town Lot area, Torrance Field, Los Angeles County	.75
29—Dominguez, Los Angeles County	1.00
30—Rosecrans, Los Angeles County	1.25
31—Inglewood, Los Angeles County	1.25
32—Seal Beach, Los Angeles and Orange Counties	1.25
33—Rincon, Ventura County	1.50
34—Mt. Poso and Poso Creek, Kern County	1.00
35—Round Mountain, Kern County	1.00
36—Kettleman North Dome and Middle Dome, Fresno and Kings Counties	1.50
37—Montebello, Los Angeles County	1.00
38—Whittier, Los Angeles County	1.25
39—West Coyote Oil Field, Los Angeles and Orange Counties	1.25
40—Elwood, Goleta (abandoned), La Goleta (gas), Santa Barbara County	1.25
41—Potrero, Los Angeles County	1.00
42—Playa del Rey, Los Angeles County	1.50
43—Capitan, Santa Barbara County	1.00
44—Mesa, Santa Barbara County	1.50
46—Richfield, Orange County	1.25
48—Mountain View and Edison, Kern County	1.25
49—Fruitvale, Kern County	1.00
50—Wilmington, Los Angeles County	1.25
51—Santa Maria Valley, Santa Barbara County	1.00
52—El Segundo and Lawndale, Los Angeles County	1.50
53—Rio Bravo and Greeley, Kern County	1.00
54—Wasco Oil Field, Buttonwillow and Semitropic (gas), Kern County	1.25
55—Canal, Canfield Ranch, Coles Levee, Strand, Ten Section, Kern County	1.25
56—Paloma, Kern County	1.25
57—Rio Vista (gas), Sacramento, Solano, and Contra Costa Counties	1.00
58—Trico Gas, Kern, Kings and Tulare Counties	1.00
59—Raisin City, Helm and Riverdale, including Wheatville area, Fresno County	1.25

o

38463 10-44 2M

STATE OF CALIFORNIA
DEPARTMENT OF NATURAL RESOURCES
WARREN T. HANNUM, Director

DIVISION OF MINES
FERRY BUILDING, SAN FRANCISCO

WALTER W. BRADLEY State Mineralogist

Vol. 40 OCTOBER 1944 No. 4

CALIFORNIA JOURNAL

OF

MINES AND GEOLOGY

QUARTERLY CHAPTER
OF
STATE MINERALOGIST'S REPORT XL

40276

DIVISION OF MINES

EXECUTIVE AND TECHNICAL STAFF

WALTER W. BRADLEY
State Mineralogist

OLAF P. JENKINS, Chief Geologist ---------- San Francisco

C. A. LOGAN, District Mining Engineer ---------- Sacramento

W. BURLING TUCKER, District Mining Engineer ---------- Los Angeles

REID J. SAMPSON, Assistant District Mining Engineer ---------- Los Angeles

CHAS. V. AVERILL, District Mining Engineer ---------- San Francisco

J. C. O'BRIEN, District Mining Engineer ---------- Redding

GEORGE L. GARY, Mineral Technologist ---------- San Francisco

JOHN F. BONGARD, Ore-Buyers' Inspector * ---------- San Francisco

HENRY H. SYMONS, Statistician and Curator ---------- San Francisco

FENELON F. DAVIS, Assistant Geologist (Librarian) ---------- San Francisco

JAMES M. LITTLE, Assistant Geologist ---------- San Francisco

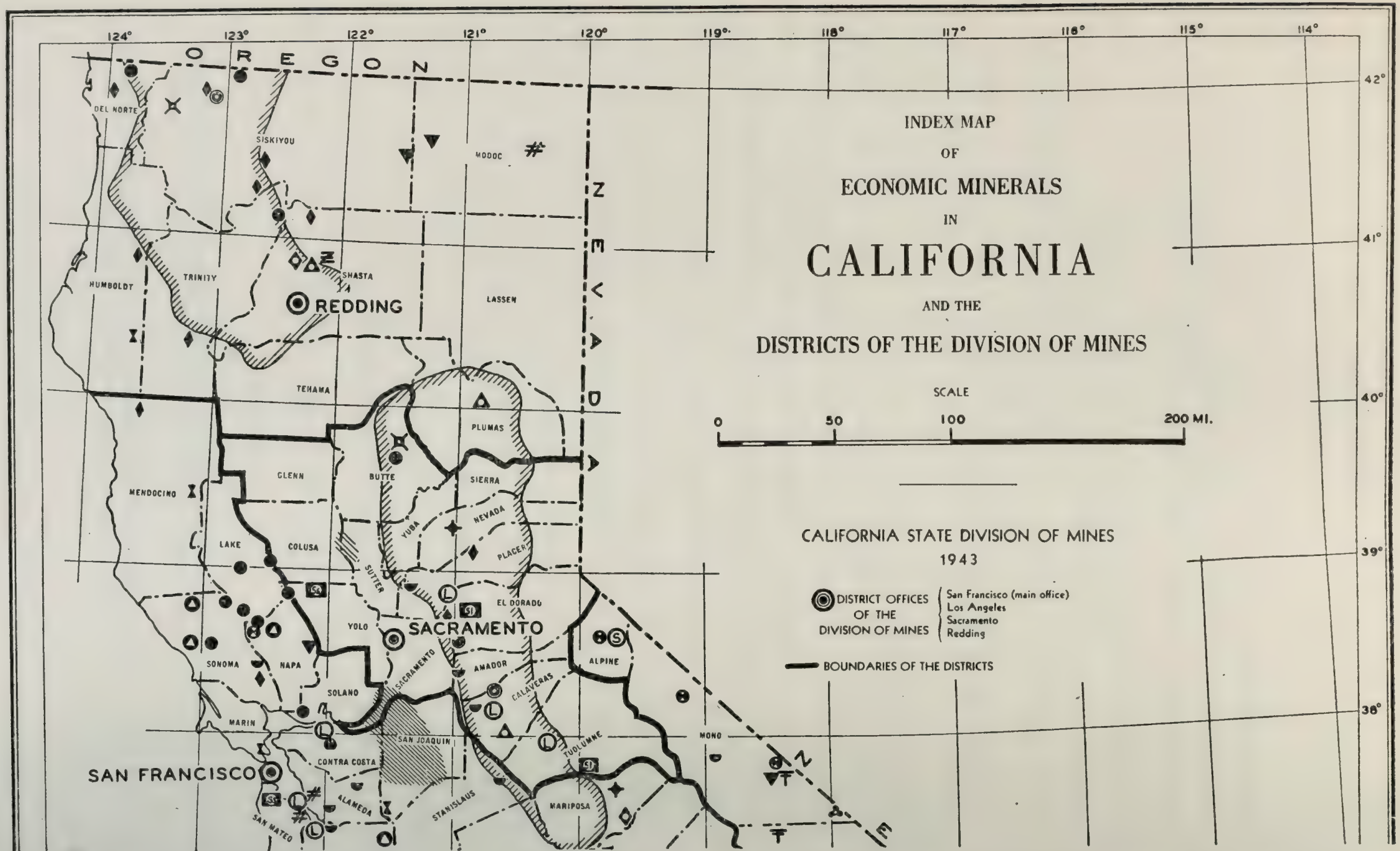
ELISABETH L. EGENHOFF, Editor, Geologic Branch ---------- San Francisco

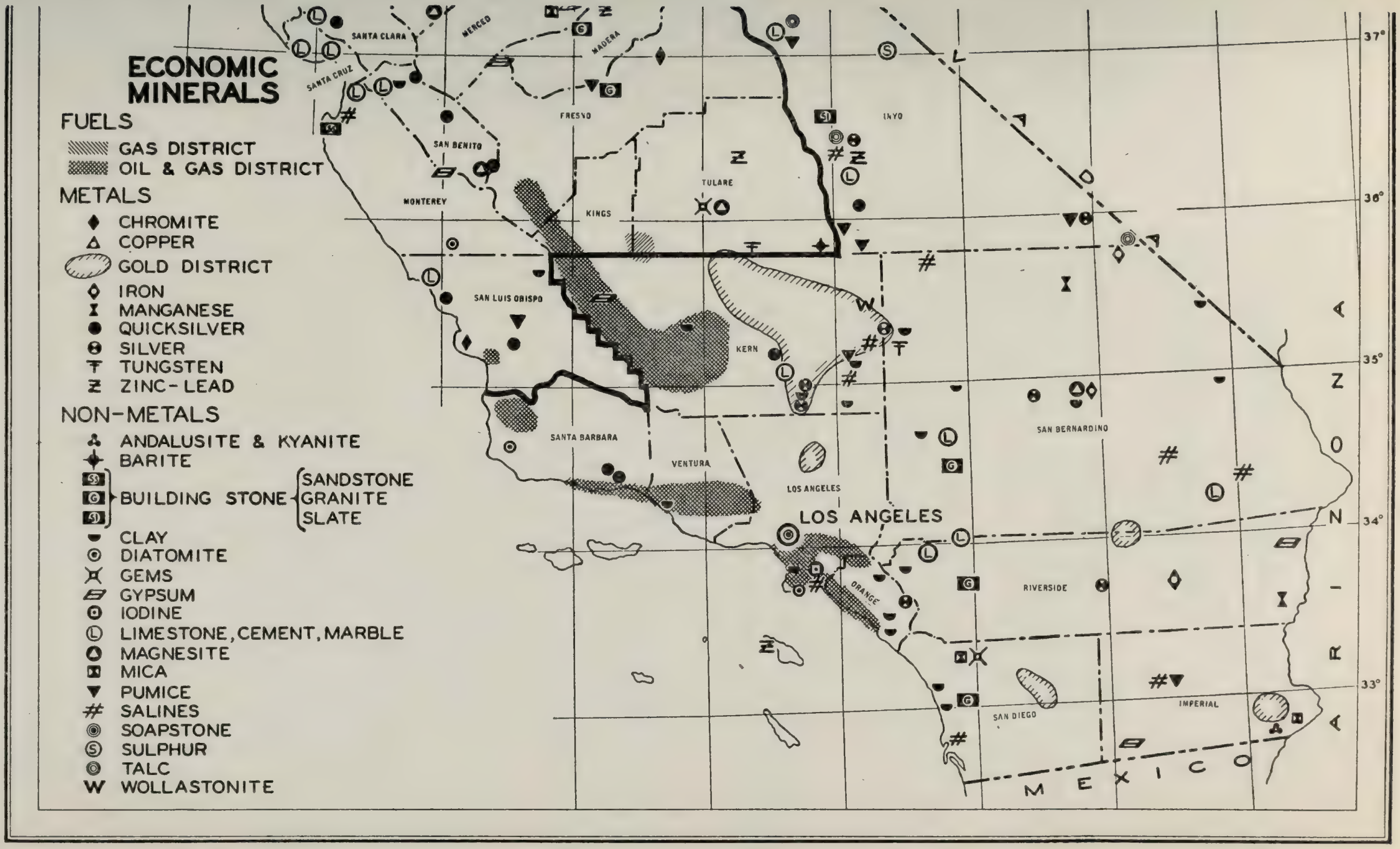
MARY H. HELM, Geological Draftsman ---------- San Francisco

* On leave for military service.

CONTENTS

PLATES


INDEX MAP
OF
ECONOMIC MINERALS
IN
CALIFORNIA
AND THE
DISTRICTS OF THE DIVISION OF MINES
SCALE
0
50
100
200 MI.
CALIFORNIA STATE DIVISION OF MINES
1943
DISTRICT OFFICES OF THE DIVISION OF MINES
San Francisco (main office)
Los Angeles
Sacramento
Redding
BOUNDARIES OF THE DISTRICTS
124°
123°
122°
121°
120°
119°
118°
117°
116°
115°
114°
42°
41°
40°
39°
38°
OREGON
NEVADA
DEL NORTE
SISKIYOU
MODOC
HUMBOLDT
TRINITY
SHASTA
REDDING
LASSEN
TEHAMA
PLUMAS
BUTTE
GLENN
SIERRA
MENDOCINO
YUBA
NEVADA
PLACER
LAKE
COLUSA
SUTTER
EL DORADO
YOLO
SACRAMENTO
ALPINE
SONOMA
NAPA
AMADOR
CALAVERAS
SOLANO
MARIN
SAN JOAQUIN
MONO
TUOLUMNE
CONTRA COSTA
SAN FRANCISCO
ALAMEDA
STANISLAUS
MARIPOSA
SAN MATEO


ECONOMIC MINERALS
FUELS
GAS DISTRICT
OIL & GAS DISTRICT
METALS
CHROMITE
COPPER
GOLD DISTRICT
IRON
MANGANESE
QUICKSILVER
SILVER
TUNGSTEN
ZINC-LEAD
NON-METALS
ANDALUSITE & KYANITE
BARITE
BUILDING STONE
SANDSTONE
GRANITE
SLATE
CLAY
DIATOMITE
GEMS
GYPSUM
IODINE
LIMESTONE, CEMENT, MARBLE
MAGNESITE
MICA
PUMICE
SALINES
SOAPSTONE
SULPHUR
TALC
WOLLASTONITE
SANTA CLARA
MERCED
MADERA
SANTA CRUZ
FRESNO
INYO
SAN BENITO
TULARE
MONTEREY
KINGS
SAN LUIS OBISPO
KERN
SAN BERNARDINO
SANTA BARBARA
VENTURA
LOS ANGELES
LOS ANGELES
RIVERSIDE
ORANGE
SAN DIEGO
IMPERIAL
NEVADA
ARIZONA
MEXICO
37°
36°
35°
34°
33°

ADMINISTRATION

ADMINISTRATIVE REPORT

By Walter W. Bradley, State Mineralogist

Personnel

On August 1, 1944, James M. Little in the San Francisco headquarters office was promoted from the grade of junior mining engineer and librarian to that of assistant geologist. He will be given field-examination assignments, assisting the chief geologist, also the district mining engineer in the San Francisco area.

On October 1, 1944, Fenelon F. Davis, geological draftsman in the San Francisco office of the Division was promoted to the grade of assistant geologist. He has been assigned to the library information service and will also make occasional field studies.

New Publications

Since last noted, the following publications of the Division of Mines have been received from the State Printer and are now available at the offices of the Division:

CALIFORNIA JOURNAL OF MINES AND GEOLOGY

October 1943, being Chapter 4 of State Mineralogist's Report XXXIX.
This chapter contains: Administrative Report; Mineral Resources of San Bernardino County; Current Notes on Activity in the Strategic Minerals, Sacramento Field District; Current Notes from the Geologic Branch, including a geologic map of a portion of the Foothill Copper Belt; a summary of the 1942 Mineral Production of California; Index to Volume XXXIX.

January 1944, being Chapter 1 of State Mineralogist's Report XL.
This chapter contains: Administrative Report; Current Notes from the Geologic Branch; three papers by William J. Miller, Professor of Geology, University of California at Los Angeles, entitled respectively "Geology of Palm Springs—Blythe Strip, Riverside County", "Geology of Parts of the Barstow Quadrangle, San Bernardino County", "Geology of the Needles-Goffs Region, San Bernardino County". Under special articles are: Airox Concrete Aggregate; Marketing Magnesite and Allied Products. Also, Accessions to the Mineral Exhibit, and a Review of California Mineral Production for 1943; Additions to Bulletin 113 on California Minerals; Library report, listing accessions and the publications available in the files, including mining district newspapers, technical magazines, and publications of state and national geological surveys as well as of technical societies, both domestic and foreign.

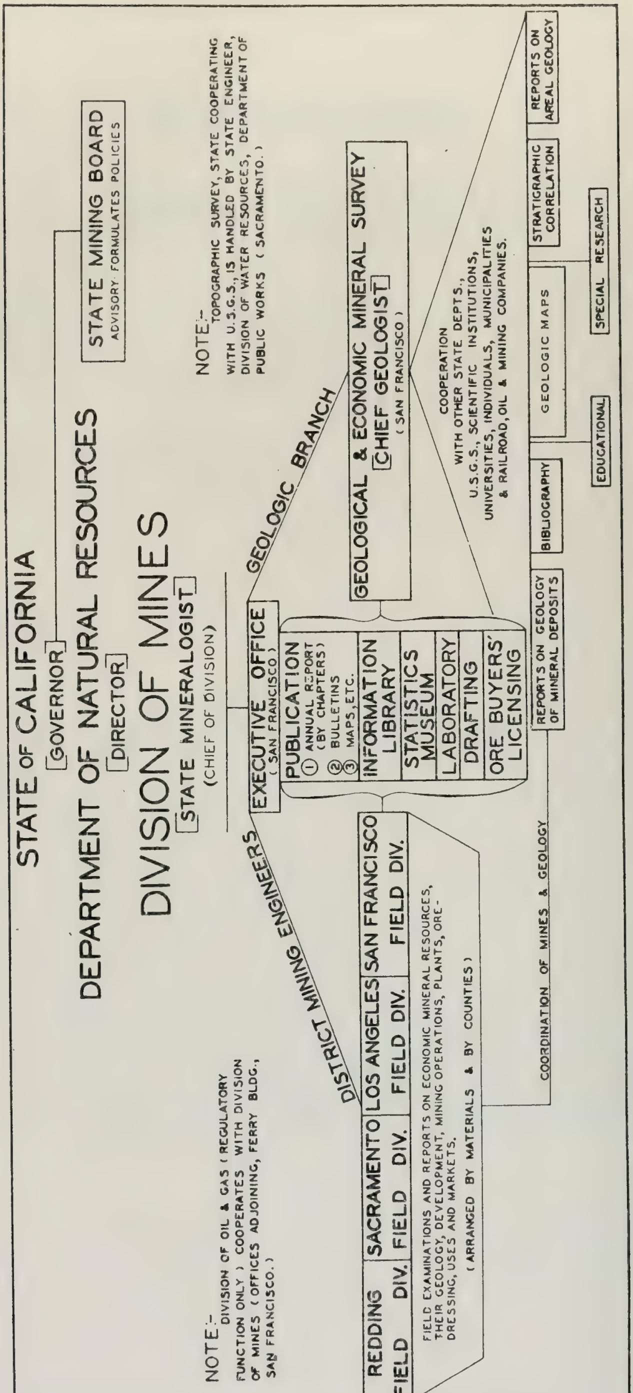


Fig. 1. Chart showing organization and functions of the California State Division of Mines

BIENNIAL REPORT OF THE STATE MINERALOGIST

General Warren T. Hannum, *Director,*
Department of Natural Resources,
Sacramento, California.

Sir: Herein I have the honor to present the biennial report of the State Mineralogist as required by law, for transmittal to His Excellency, Governor Earl Warren, covering the work and activity of the Division of Mines of the Department of Natural Resources, for the period of July 1, 1942 to June 30, 1944.

GENERAL SUMMARY

This division of California's State governmental activity has now had an unbroken history of 64 years since its creation by legislative enactment as the "State Mining Bureau," signed by Governor George C. Perkins, April 16, 1880. It was included as a division of the Department of Natural Resources when the department was created by the legislature in 1927. The organization chart, made a part hereof, shows the present-day set-up of the Division, its relation to other divisions of the department, and its cooperation and coordination with other institutions or surveys, Federal, State, and educational.

With reference to our cooperative and coordinated endeavors with other institutions, I am pleased to say that we continue to have and are enjoying the most cordial and appreciated relations with such groups as the United States Geological Survey, United States Bureau of Mines, other Federal institutions (specifically the Reconstruction Finance Corporation and its Metals Reserve Company, also the War Production Board), the geological and mining engineering departments of the several universities in California (as well as some outside of this State, whose men have done professional work within our borders), also with the operating mining and oil companies throughout California.

Besides the main headquarters with offices in the Ferry Building, San Francisco, including the library, laboratory, and mineral exhibits, district mining engineers are stationed with offices at Sacramento, Los Angeles and Redding. Reports and bulletins to a total number of 168 over the 64 years have been published, describing in detail (with maps, charts and photographs) the varied mineral substances available in this great commonwealth of California—their location, character, transportation facilities, state of development, utilization, and other pertinent facts.

California is an extensive empire and has widespread and diversified resources of minerals not excelled by any other equal area on the face of the planet. It is a big task for the small staff of the Division of Mines to adequately cover this large assignment and keep up-to-date on the economic developments in all of the varied industries and areas within our borders. Since the beginning of war operations in Europe and especially since December 7, 1941, with the entrance of the United States into the conflict, much attention has been given to inventorying and developing our domestic resources of certain "strategic" minerals

important to the United States in the war program. These include specifically quicksilver, chromite, manganese, tungsten, antimony, piezoelectric quartz, as well as others, of which California has both currently active and potential resources. Printed reports, bulletins and maps have been made available on quicksilver, petroleum, chromite, tungsten, and manganese, and others on copper, iron, and zinc are in the course of preparation. A list is included elsewhere herein of the papers, bulletins, reports, maps, and other publications issued during this biennial period.

The function of Emergency Coordinator for Mines under the War Production Board dealing with priority operating permits under Order P-56 continued active during the first year of this biennium. In 1943 the district mining engineer of the War Production Board stationed in the San Francisco office was given a measure of authority to grant permits in the majority of cases without reference to Washington headquarters. Since then, such cases are not being routed through the State Mineralogist's office. A similar situation obtains in the case of applications for small loans for mines to the federal Reconstruction Finance Corporation. A total of 103 applications were referred to the Division for investigation by our engineers. Loans were granted to 42 properties of those recommended favorably. No applications have been received since February 1944. The clerical, cataloguing, indexing, book-binding, and map-making project, under assistance of the Works Progress Administration was closed at the end of the calendar year 1942. One valuable accomplishment of that project which is a permanent asset to the Division's library was the binding of a large number of pamphlets, paper-covered books, and magazine files.

The following figures on the receipts from publication sales for the biennium are of interest:

$4,072.95—July 1, 1942 to June 30, 1943.
$10,065.60—July 1, 1943 to June 30, 1944.

The increase in the second year was due to completion of three outstanding bulletins (No. 123, "American Mining Law"; No. 125, "Manganese Resources of California"; No. 118, "Geologic Formations and Economic Development of the Oil and Gas Fields of California"), which sell for $5.00, $3.00 and $6.00, respectively. Over-the-counter sales in each of the two years were divided among the three offices of the Division (none are sold at Redding), as follows:

San Francisco—$867.15 and $1,307.70
Los Angeles—$708.45 and $1,355.05
Sacramento—$197.75 and $226.05
Mail orders—San Francisco—$1,871.80 and $6,617.80
Subscriptions—(Journal of Mines and Geology) $427.80 and $559.00

GEOLOGIC BRANCH

During the past two years the Geologic Branch of the Division of Mines has expanded its program of cooperative work with other agencies and institutions. One of the most important results of this cooperation has been the publication of Bulletin 125, *Manganese in California*, which contains the following contributions:

(1) *History of the manganese industry*, by Robert Scott Kroger (Department of Mining, Stanford University), pp. 13-21.

(2) *Occurrence and minerals of manganese*, by Theo H. Crook (Department of Geological Sciences, University of California), pp. 23-40.

(3) *Utilization of California manganese ores*, by O. Cutler Shepard (Department of Mining, Stanford University), pp. 41-49.

(4) *Manganese deposits of California—a summary report (including tabulated data on manganese properties of California)*, by Parker D. Trask, Ivan F. Wilson, and Frank S. Simons (U. S. Geological Survey), pp. 51-215.

(5) *Genesis of the manganese deposits of the Coast Ranges of California*, by N. L. Taliaferro and F. S. Hudson (Department of Geological Sciences, University of California; Yuba Manufacturing Company), pp. 217-275.

(6) *Manganese deposits of the Sierra Nevada, their genesis and metamorphism*, by N. L. Taliaferro (Department of Geological Sciences, University of California), pp. 277-332.

(7) *Outline geologic map of California showing locations of manganese properties* (Economic Mineral Map No. 5, Manganese), scale 1:1,000,000, by Olaf P. Jenkins (State Division of Mines).

A number of other State-wide projects are planned by the Geologic Branch for the future. A bulletin and map covering the iron deposits of California are now in preparation, material for which is being contributed by the U. S. Geological Survey, supplemented by investigations of our staff members. As in the case of the manganese bulletin this work is being donated by outstanding men in the geological and engineering professions, *the only cost to the State being the actual cost of publication*, which is eventually nullified by sales. This fine spirit of cooperation in bringing information on geology and mining to the public is much appreciated by the Division.

Dr. Olaf P. Jenkins of the Geologic Branch has recently completed an intensive study of the topographic and geologic mapping that has been done in California. As a result of this study, the Division of Mines has been able to submit to the State Reconstruction and Reemployment Commission a post-war plan to complete the topographic mapping of the State on the scale of 1:62,500, with the following objectives in mind:

(1) To provide a uniform topographic map of the State, on a scale adequate for geologic mapping. These maps are particularly needed for mining regions, mapping of which has been neglected in favor of agricultural regions.

(2) To get this mapping done by the Multiplex method which employs aerial photographs. The result is a more accurate, larger scale, but less expensive map than that prepared from ground surveys.

(3) To get this mapping done at the least possible expense to the State. The Geological Survey, Department of the Interior, is the chief topographic mapping agency in the United States. This agency will match State appropriations on a 50-50 basis.

(4) To stimulate geological mapping of areas newly mapped topographically.

(5) To provide the mining industry with the adequate tools—geologic maps—for exploration; to so stimulate discovery of new deposits, which will in turn stimulate the expansion of the mining industry, and provide employment for qualified men released from military service.

It is the contention of the Division of Mines that California has unknown mineral reserves that could be brought to light by scientific prospecting based on a study of accurate and detailed regional geology; also, that exploitation and development of known deposits are actually dependent on, or could be greatly facilitated by accurate geologic information and proper interpretation of geologic data. Therefore, the Geologic Branch is most anxious to have established an adequate topographic mapping program, for upon this, any program of geologic mapping and mineral discovery necessarily would be dependent.

During this last biennium the Geologic Branch published the first of its series of geologic maps of quadrangles, the *San Benito quadrangle,* by Ivan F. Wilson. This map corresponds to the United States Geological Survey folio maps, but is on the scale of 1:62,500. It shows geology and mineral deposits, and is accompanied by an 87-page report. This work too was contributed to the State, the only cost being that of publication. The Geologic Branch plans to continue this series of maps until all of California has been covered.

The most ambitious undertaking of the Division of Mines—with the possible exception of the Geologic Map of California—was released in its entirety during 1943. This was the 773-page Bulletin 118, *Geologic formations and economic development of the oil and gas fields of California,* contributed by 126 geologists. The petroleum industry has been as cordial and generous in receiving this volume as in contributing to its pages.

In addition to Bulletins 118 and 125, the following publications have been released by the Geologic Branch:

(1) *Mylonites in the eastern San Gabriel Mountains,* by Raymond M. Alf (Webb School of California, Claremont), April 1943 *Journal,* pp. 145-151.

(2) *Geology of the Sierra Nevada northeast of Visalia, Tulare County, California,* by Cordell Durrell (Department of Geological Sciences, University of California) April 1943 *Journal,* pp. 153-168, geologic map.

(3) *Tungsten deposits northeast of Visalia, California,* by William O. Jenkins, April 1943 *Journal,* pp. 169-182.

(4) *Geology of the San Benito quadrangle, California,* by Ivan F. Wilson (Department of Geological Sciences, University of California), April 1943 *Journal,* pp. 183-270; includes geologic map, scale 1:62,500.

(5) *Crestmore minerals,* by A. O. Woodford (Pomona College), July 1943 *Journal,* pp. 333-365.

(6) *The Isometrograph as developed and used at the New Idria quicksilver mine,* by J. McLaren Forbes (New Idria Quicksilver Mining Company), July 1943 *Journal,* pp. 367-376.

(7) *Discussion of Bulletin 118—notes relating to Sutter (Marysville) Buttes gas field,* by Walter Stalder, July 1943 *Journal,* pp. 377-381.

(8) *Geologic map of a portion of the Foothill Copper Belt, Calaveras County, California,* scale 1″ = 800′, by Ben M. Page, Stanford Geological Survey, October 1943 *Journal,* Pl. VIII.

Geologic Branch publications in press at the present time (September 15, 1944) are:

(1) *Geology of Palm Springs—Blythe strip, Riverside County, California,* by William J. Miller (University of California at Los Angeles), January 1944 *Journal.* Includes geologic map.

(2) *Geology of parts of the Barstow quadrangle, San Bernardino County, California,* by William J. Miller (University of California at Los Angeles), January 1944 *Journal.* Includes geologic map.

(3) *Geology of the Needles-Goffs region, San Bernardino County, California,* by William J. Miller (University of California at Los Angeles), January 1944 *Journal.* Includes geologic map.

(4) *Status of topographic and geologic mapping in California,* by Olaf P. Jenkins (Division of Mines, Geologic Branch), April 1944 *Journal.* Includes index maps.

(5) *Geology of the Jamesburg quadrangle, Monterey County, California,* by William Morris Fiedler (Department of Geological Sciences, University of California), April 1944 *Journal.* Includes geologic map, scale 1:62,500.

(6) *Mines and quarries of the Indians of California,* by Robert F. Heizer and Adan E. Treganza (Department of Anthropology, University of California), July 1944 *Journal.*

(7) *Minarets magnetite deposits of Iron Mountain, Madera County, California,* by Parker D. Trask and Frank S. Simons (United States Geological Survey). Includes map.

(8) *Iron ore deposits in the eastern part of Eagle Mountains, Riverside County, California,* by Jarvis B. Hadley (United States Geological Survey). Includes maps.

The Geologic Branch has a number of interesting reports in preparation, some of which are nearing completion, and should soon be ready for publication:

(1) *Kramer borate district,* by Hoyt Gale and Rodney Gale.

(2) *Minerals of California* (revision of Bulletin 113), by Joseph Murdoch and Robert W. Webb (University of California at Los Angeles).

(3) *Geology of the Copperopolis quadrangle,* by N. L. Taliaferro (University of California, Department of Geological Sciences). Includes geologic map, scale 1:62,500.

LABORATORY

Our Mineral Technologist, George L. Gary, reports that the laboratory of the Division headquarters has identified and classified approximately 16,000 samples, mailed or brought into the Division, during the biennium. A written laboratory report is given on each sample, and commercial possibilities, if any, are noted. These reports are further supplemented by articles concerning the ore mineral in question.

Samples were received from all of California's 58 counties, mainly from the southern part of the State. Due to the war requirements and the gold closing order, 80 percent of the requests accompanying the samples were for strategic minerals, such as quicksilver, chromite, tungsten, manganese, antimony, copper, zinc, mica, quartz, aluminum, and magnesium. Approximately 20 percent of California's 70-odd commercial minerals are vitally needed by our war industries and fully 10 percent of the samples examined had commercial possibilities. This information was made available to the public through our files and Monthly Commercial Mineral Notes.

Approximately 60 papers have been prepared and revised under the direction of the Mineral Technologist upon the commercial minerals of California. In April 1941, the first papers of this series were mimeographed; they were originally run off in lots of five to fifteen hundred, depending upon the importance of the subject. Several of the papers on strategic or critical minerals have been rerun 10 or 15 times.

These papers are distributed through the main office of the Division of Mines and our regional offices at Los Angeles, Sacramento and Redding. They are available for reference at many of the public libraries and universities of the Western States, as are our other publications. Certain of these papers have been reprinted by technical journals, magazines, and newspapers.

As there has been a demand for a complete series, it was decided to issue these papers as a loose-leaf bulletin. This Bulletin No. 124 is so arranged that it may be revised and expanded as marketing conditions change, and it is the intention of the Division of Mines, as these changes occur, to supplement this bulletin with additional up-to-the-minute information on the properties, occurrences, preparation, uses, tests, markets, and possible buyers, with selected bibliographic references concerning these commercial minerals.

The work being done by the laboratory to train men to prospect for strategic minerals, needed by the Government, is being continued by Mr. Gary at the San Ramon Union High School, Danville, in Contra Costa County. This program has been under way for two years and the results have been very encouraging. The students are of the executive type, holding responsible jobs, or owning their own businesses; and the attendance has been remarkable in view of the demands made upon their time due to the war. This class was designed and operated as a potential reservoir of manpower that could be used in field or plant duty by the mineral industry, and it has proved its worth by furnishing men for these purposes.

Field trips have been made by the class to new or operating properties with the idea of securing new production or increasing old production and it is with considerable pleasure that the Division of Mines can point to letters in its files attesting and confirming the success of this program. This class, sponsored by the Division of Mines, was instrumental in bringing about a consolidation of interests which resulted in the expanded operation of one of California's largest present-producing copper mines.

The class instruction in mineralogy is divided into four parts. The first consists of blackboard lectures on the identification of rocks and the origin, occurrence, and association of minerals; the second consists of the identification of strategic and commercial minerals; the third consists of the chemical examination of minerals and the general principles of chemistry as applied to minerals; the fourth consists of field trips to various parts of the State where commercial minerals are found, and brings the student in contact with actual operations.

The class has advanced to where, at the present time, the members are able to do satisfactory work on the overflow samples of the laboratory. This is, of course, checked by our Mineral Technologist, before the reports are sent out. The men engaged in this work devote three and one-half hours of their time each night, four nights a week, and a field trip once a month, to aid the mining industry and the war effort, which has to some extent offset the insufficient appropriation requested in our last budget for laboratory aid.

ORE BUYERS' INSPECTION

Since the issuance of the War Production Board's Order L-208, October 8, 1942, the gold mines of the entire mining west, with a few specific exceptions, have been completely shut down. Small mines with less than seven men employed, hydraulic mines and dredges with limited crews of men over 45 years of age, were permitted to continue. Also, limited crews were allowed the larger, deep, lode-gold mines for maintenance purposes.

During the period under review the following numbers of gold-buyers' licenses have been issued:

Year	*Limited (@ $2.00)*	*Unlimited (@ $15.00)*
1942	66	45 (including 5 banks)
1943	47	56 (including 8 banks)
1944	47	48 (including 8 banks)

''Limited'' licenses allow purchases to a total of $1,000.00 per calendar year; and ''Unlimited'' licenses allow over $1,000.00 in total purchases annually.

PUBLICATIONS

Publications issued July 1, 1942 to June 30, 1944:

July and October chapters *California Journal of Mines and Geology* of the State Mineralogist's Report XXXVIII. Among the more important subjects are:

Hot Springs Deposits of the Coso Mountains, Inyo County.
Contact Metamorphic Rocks of the Twin Lakes Region, Fresno County.
Tungsten Deposits of the Confidence Mining District, Tuolumne County.
Geology of the Welsh Tungsten Deposits, Madera County.
Ghost Canyon Tungsten Claims, Madera County.
Tabulation of Tungsten Deposits of California to accompany Economic Mineral Map No. 4.

Special Articles:
Biennial Report of the State Mineralogist.

State Mineralogist's Report XXXIX, 1943. Among the more important subjects included are:

Organization and Service of the Division of Mines.
Mines and Mineral Resources of Santa Cruz County.
Discoveries in the Strategic Minerals, San Francisco Field District.
Current Notes on Activities in the Strategic Minerals, Los Angeles Field District.
Current Notes on Activity in the Strategic Minerals, Sacramento Field District. (January, April, July and October quarterlies.)
Current Notes on Activity in the Strategic Minerals, Redding Field District. (January and July quarterlies.)
Current Mining Activity in Plumas County.
Department of the Interior Information Service, by United States Geological Survey.
Review of California Mineral Production for 1942.
Manganese Discovery in San Mateo County.
Current Mining Activity in Southern California.
Clerbus-Mae Tungsten Prospect, Trinity County.
Mylonites in the Eastern San Gabriel Mountains.
Geology of the Sierra Nevada Northeast of Visalia, Tulare County.
Tungsten Deposits Northeast of Visalia, Tulare County.
Geology of the San Benito Quadrangle, San Benito County.
Carbon Dioxide Gas Occurrences in Mendocino and Northern Sonoma Counties.
Crestmore Minerals, Riverside County.
The Isometrograph as Developed and Used at the New Idria Quicksilver Mine, San Benito County.
Notes Relating to Sutter (Marysville) Buttes Gas Field, Sutter County.
Mineral Resources of San Bernardino County.
Geologic Map of a Portion of the Foothill Copper Belt in Calaveras County.

Special Articles on:
The Sillimanite Group of Minerals.
New Federal and State Legislation Affecting Mining.

January and April, 1944, chapters (*California Journal of Mines and Geology*) of State Mineralogist's Report XL. Among the more important subjects included are:

Geology of Palm Springs-Blythe Strip, Riverside County.
Geology of Parts of the Barstow Quadrangle, San Bernardino County.
Geology of the Needles-Goffs Region, San Bernardino County.
Status of Topographic and Geologic Mapping in California.
Geology of the Jamesburg Quadrangle, Monterey County.
Mines and Quarries of the Indians of California.

Special Articles on:
Fluorescent Minerals.

Bulletin 118. *Geologic Formations and Economic Development of the Oil and Gas Fields of California.* Prepared under the direction of Olaf P. Jenkins.

Preprint of Part III. Descriptions of Individual Oil and Gas Fields.

Preprint of Part IV. Glossaries, Bibliography and Index.

Also the complete, cloth-bound volume, comprising 774 pages (8 by 11 inches, instead of the usual 6 by 9 inches), 372 illustrations, accompanied by *Economic Mineral Map No. 2, Oil and Gas* in pocket.

Bulletin 122. *California Mineral Production and Directory of Mineral Producers for 1941*, by Henry H. Symons, 377 pages, 8 illustrations. Gives detailed figures of commercial production of all mineral substances in California for the calendar year, 1941. Also has cumulative tables of total recorded mineral production for each of the 58 counties to and including the year 1941.

Bulletin 123. *American Mining Law*, by A. H. Ricketts, 1,018 pages, 23 illustrations. This is a revision of the earlier (1931) Bulletin 98 by the same author.

Bulletin 124. *Commercial Minerals of California*, prepared under the direction of George L. Gary, mimeographed and loose-leafed, 165 pages, by separate mineral substances.

Bulletin 125. *Manganese in California*, prepared under the direction of Olaf P. Jenkins, with the following contributing authors: Theo H. Crook, Frank S. Hudson, Olaf P. Jenkins, Robert S. Kroger, O. Cutler Shepard, Frank S. Simons, N. L. Taliaferro, Parker D. Trask, Ivan F. Wilson, and with the following cooperating agencies: United States Geological Survey; Department of Geological Sciences, University of California; Department of Mining, Stanford University; 387 pages, 46 illustrations, accompanied by Outline Geologic Map of California showing locations of Manganese Properties (Economic Mineral Map No. 5) in pocket.

Bulletin 126. *California Mineral Production and Directory of Mineral Producers for 1942*, by Henry H. Symons, 224 pages, 7 illustrations. Gives detailed figures of commercial production of all mineral substances in California for the calendar year 1942.

Bulletin 127. *Manner of Locating and Holding Mineral Claims in California (with Forms)*, by A. H. Ricketts, with revisions by C. A. Logan, March, 1944. This is a seventh edition of the popular summarized mining law bulletin issued first as Bulletin 106 in 1931, with revisions and inclusion of the new statutory requirements added to the mining law to and including the 1943 session of the legislature.

CONCLUSION

The Division of Mines is the only State agency here fostering the economic development of these varied and vital resources. The staff of mining engineers and geologists should be augmented and the program of field work expanded, and added funds provided for printing of these, and contributed, reports and maps. It is thus that the data and information gathered by field examinations are disseminated and capital shown the way to economic investments in California. It should also be remembered that the moneys spent on printing come back to the State Treasury from the sales of the publications.

Respectfully submitted.

Walter W. Bradley,
State Mineralogist

September 15, 1944.

GEOLOGIC BRANCH

CURRENT NOTES

BY OLAF P. JENKINS *

In This Issue

Phosphorite. The following paper contributed by Dr. Austin Flint Rogers, Professor Emeritus of Mineralogy, Stanford University, *Pellet Phosphorite from Carmel Valley, Monterey County, California,* should serve as a guide to prospecting for commercial "phosphate rock" in this State. If this mineral could be found in sufficient quantity and in a suitable locality in California, it would be of great service to the agricultural development of this State. It is quite possible that a discovery may be made in the future, because large deposits of phosphorite of high grade are known to occur (inaccessible to commercial operations) off the coast of California.

Quartz Crystal. In the search for quartz crystal suitable for optical and radio purposes, the Federal Geological Survey has made a geological examination of the well-known deposit near Mokelumne Hill. In this issue of the Journal the Survey has contributed *Geology of the Quartz-Crystal Mines Near Mokelumne Hill, Calaveras County, California,* by Cordell Durrell.

The following statements on the significance of quartz crystal are excerpts from further communication with Dr. Durrell:

"Quartz crystals are very common in California and Nevada, but deposits of crystals that are suitable for optical and radio use and which may be exploited commercially are indeed rare . . . In general, in order that a crystal be usable, it must be clear and free of fractures, bubbles, inclusions, twinning, and other defects for a region of at least two cubic inches. External stains or coatings such as iron oxide are not detrimental though they must generally be removed in order that the crystal may be inspected . . .

"Deposits of quartz crystals are of four principal types: pegmatites, tactites, hydrothermal veins, and placer deposits. A few primary deposits which lack critical characteristics are probably either hydrothermal in origin or are pegmatites. The primary source of crystals in placer deposits may only be inferred. Quartz crystals of interest to collectors occur in still other situations, but crystals from them are not likely to be usable . . .

"The presence of quartz crystals in the auriferous gravels of the Sierra Nevada has long been known. Crystals have not been reported in placers elsewhere in California or Nevada. The only quartz-crystal occurrence in this region upon which practical mining operations have been undertaken is the placer deposit near Mokelumne Hill . . . The crystals are of uncommonly large size, and in some cases exceeding 100 pounds in weight. Some usable crystal has been obtained from the deposits near Mokelumne Hill.

* Chief Geologist, State Division of Mines.

"It is strange that no veins containing such large crystals have been discovered in the region where the placers occur, and it must be supposed that they are buried beneath the extensive Tertiary rocks of the region, or were completely removed by erosion . . ."

Forthcoming Publications

Silica Minerals. Now in preparation is a paper by Dr. Austin Flint Rogers on the silica minerals of California.

Quicksilver. In the January 1945 issue of the Journal will appear an article contributed by the U. S. Geological Survey on *Quicksilver Deposits of Central San Benito and Northwestern Fresno Counties, California,* by Robert G. Yates and Lowell S. Hilpert.

Several other papers on quicksilver, prepared and contributed by the Survey, will be published in forthcoming issues.

PELLET PHOSPHORITE FROM CARMEL VALLEY, MONTEREY COUNTY, CALIFORNIA

By Austin F. Rogers *

OUTLINE OF REPORT

INTRODUCTION

Two interesting deposits of calcium phosphate occur about half a mile apart in the Carmel Valley, approximately 11 miles east of the City of Carmel. They are exposed in cuts on the main road up the valley, on the north side of Carmel River, within a mile of the eastern border of the Monterey topographic quadrangle of the United States Geological Survey.

Dr. Hubert G. Schenck first called these deposits to the attention of the author, who, in 1937, collected some of the specimens used for this paper. Recently Dr. Olaf P. Jenkins visited the locality and obtained additional material which he turned over to the author for study.

It seems likely that the phosphate of this region was first found by Mr. Franklin A. Luis** of Salinas. Mr. Luis collected a specimen from a locality in this vicinity and made a record in his notebook on June 15, 1912. This specimen was determined to be collophane by the writer about 1920.

The phosphorite [1] is in poorly defined beds, 6 to 8 inches thick near Tomasin Canyon, and about 1 foot thick east of Juan de Matte Canyon, in typical Monterey shale.[2] In the field the rock was thought to be an oolite, but examination of thin sections showed that the majority of the supposed ooliths have neither concentric nor radial structure. Blackwelder [3] suggested that similar phosphatic grains without oolitic struc-

---

* Emeritus Professor of Mineralogy, Stanford University, California. Manuscript submitted for publication October 6, 1944.

** Oral communication, Dec. 15, 1944.

[1] The term phosphorite is used here for sedimentary calcium phosphate rock made up essentially of collophane and/or dahllite. In Great Britain it is called *rock phosphate* and in the United States it is usually known as *phosphate rock*. Neither of these names is satisfactory. Following most Continental geologists and petrographers, the author prefers the term *phosphorite*. It is true that "phosphorite" was used as the mineralogical name for a variety of apatite by Bowles (1782) and Kirwan (1794), and apparently sanctioned in the sixth edition of Dana's *System of Mineralogy* in 1892. But one of the limitations of the law of priority set forth by Dana is that a name may be set aside when it "has been lost sight of and has found no one to assert its claim for a period of more than fifty years" (see p. xliii of Dana). Since no one has given an accurate definition of phosphorite as a mineral or mineral variety within the 50-year period (1892-1942) its use as a rock name is defended.

[2] Galliher, E. Wayne, Collophane from Miocene brown shales of California: Am. Assoc. Petroleum Geologists Bull., vol. 15, p. 266, 1931.

Fiedler, William Morris, Geology of the Jamesburg quadrangle, Monterey County, California: California Div. Mines Rept. 40, pp. 248-249, 1944.

[3] In Twenhofel's *Treatise on Sedimentation*, 1st ed., p. 396, Baltimore, 1926.

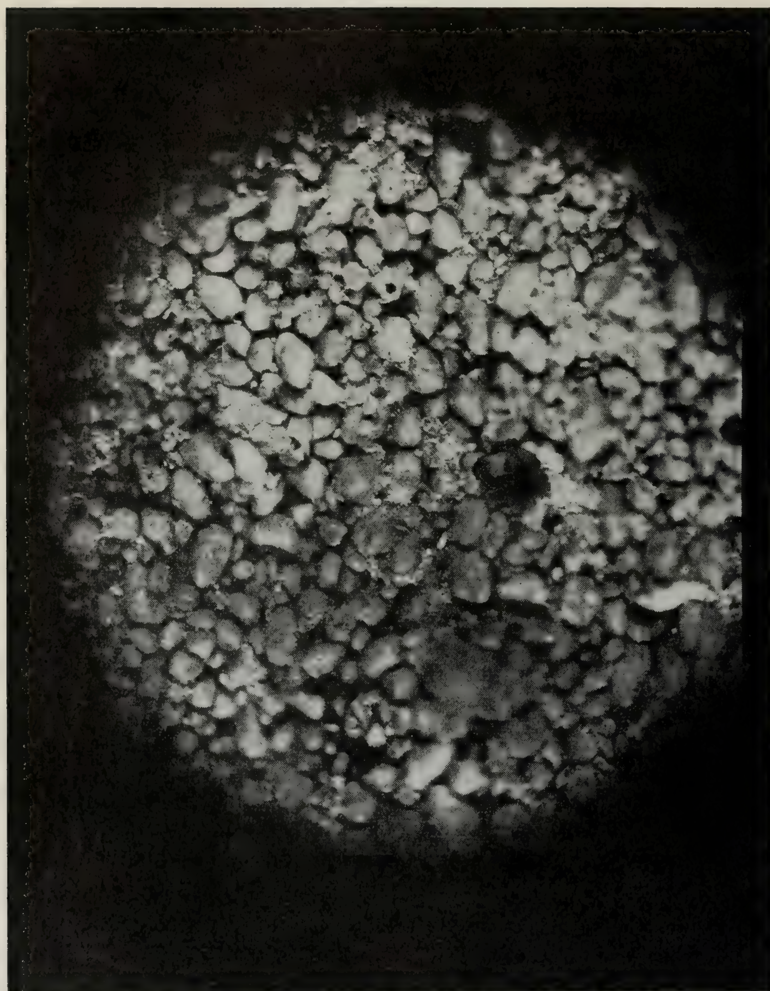


FIG. 1. (× 13) Broken surface of pellet phosphorite as seen with hand lens. Carmel Valley.

FIG. 2. ($\times 2\frac{1}{3}$) Section roughly ground, normal to the bedding plane, showing pellet texture in contrast with light-colored siliceous shale. Carmel Valley.

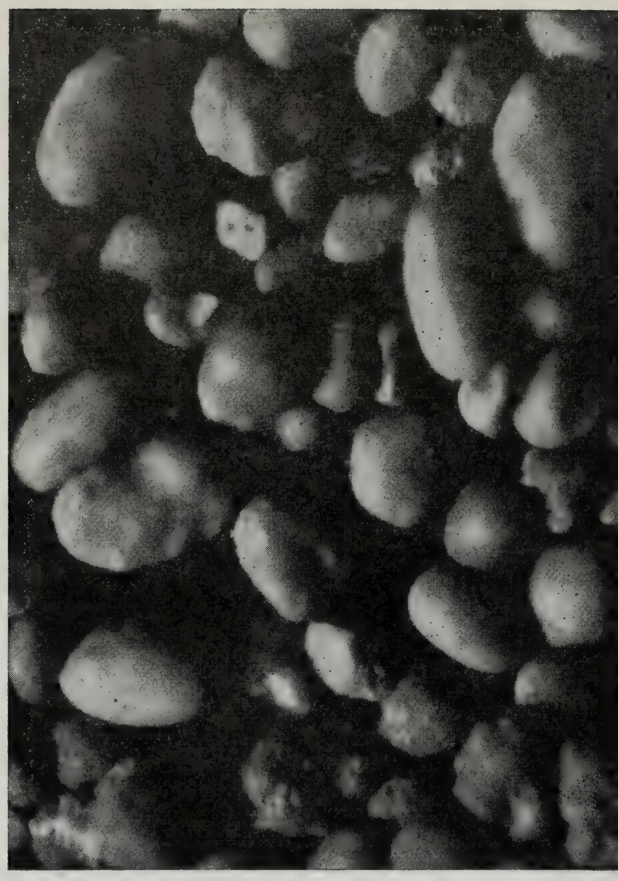


FIG. 3. (× 36) Pellets from the pellet phosphorite of Carmel Valley.

ture may be coprolites. While the Carmel Valley pseudo-ooliths are in all probability micro-coprolites, it seems better to employ the non-committal term *pellet*.

Similar phosphatic material is mentioned by Kleinpell[4] in referring to the rocks of the type locality of the Luisian stage in San Luis Obispo County. He says: "The top of the Luisian is the horizon at which organic shale with diatomite and chert concretions is overlain by sand and silt carrying buff phosphatic pellets."

Except in color the pellets mentioned here are similar to the pyritized collophane oolites or pellets found in the rocks of the southern San Joaquin Valley and generally known as "sporbo" by petroleum geologists.[5]

DESCRIPTION OF THE PHOSPHORITE

The phosphorite is a buff-colored (close to Ridgway's 19″) loosely consolidated sediment made up of pellets of collophane with admixed detrital material and a minor amount of siliceous shale matrix. The pellets vary from ellipsoidal to sub-spherical and range from about 0.1 millimeter to about 1 millimeter in size. The great majority of them go through a 40-mesh sieve but are caught on a 60-mesh sieve. Figure 1 shows the general character of a broken rock surface. In figure 2, which is a photograph of a roughly ground surface cut normal to the bedding plane, the darker collophane pellets are seen embedded in typical, almost white siliceous shale. Thus the phosphatic bed varies from a rather high-grade phosphorite to a low-grade phosphatic siliceous shale.

The pellets can be separated easily from their matrix by dry grinding the phosphorite on abrasive paper. Some of these separated pellets are shown in figure 3. They are smooth and may be cleaned by agitation in a beaker of water. Crushed fragments of the pellets are isotropic and have an index of refraction of $1.613 \pm .003$ (determined by the immersion method with liquids of known indices). The fragments are not homogeneous but have distributed through them minute isotropic particles with an index of refraction much less than that of the collophane. This material is probably diatom debris and some admixed siliceous shale. This is an argument in favor of their coprolitic nature.

CHEMICAL TESTS

The pellets are easily soluble in hot dilute nitric acid, with effervescence. An insoluble residue is left and a rough determination showed that it amounts to approximately 5 percent. An excellent phosphate test was obtained with ammonium molybdate. A quantitative analysis of the cleaned pellets made by Mr. Kenneth C. Peer of the Ragooland-Broy Laboratory of San Francisco gave 33.11 percent of P_2O_5, which corresponds to 72.33 percent of tri-calcium phosphate $[Ca_3(PO_4)_2]$. Qualitative tests indicate the presence of a very large amount of calcium, a fair amount of aluminum, no appreciable iron, and a small amount of magnesium. These tests were made by first precipitating calcium sulphate with 50 percent ethyl alcohol and dilute sulphuric acid and then testing the filtrate for the other metals. This procedure is advisable

[4] Kleinpell, R. M., Miocene stratigraphy of California, p. 122, Am. Assoc. Petroleum Geologists, Tulsa, 1938.
[5] Galliher, E. Wayne, op. cit.

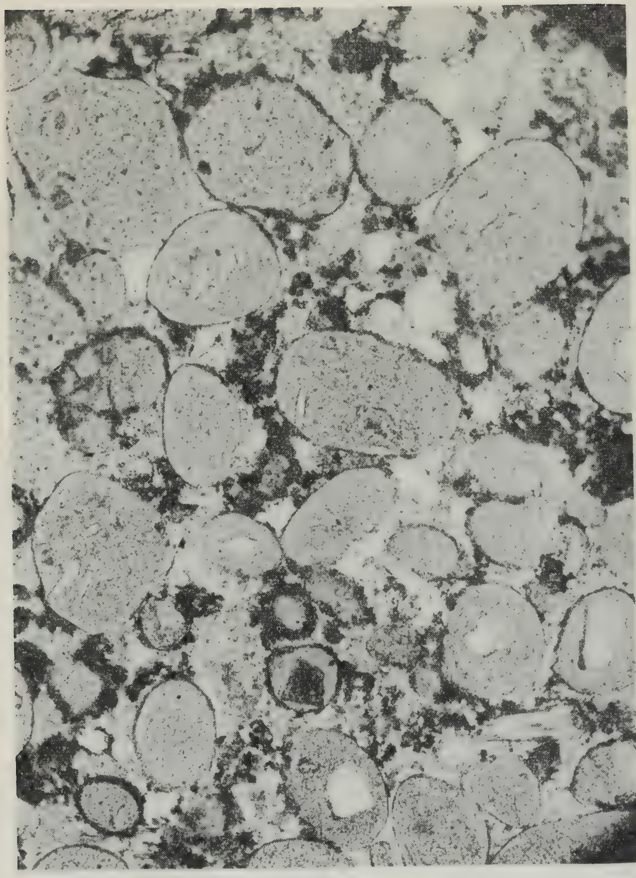


FIG. 4. (× 36) Thin section of pellet phosphorite of Carmel Valley.

since with an acid solution of calcium phosphate, ammonium hydroxid precipitates calcium phosphate along with aluminum hydroxid. Heated in a closed tube the pellets turn dark and give a fair amount of water at a comparatively low temperature.

THE PELLETS ARE COLLOPHANE

The foregoing tests indicate that the pellets consist largely of collophane. The formula of collophane (or collophanite) is often given as $Ca_3(PO_4)_2.H_2O$ but this is an error copied and recopied from the sixth edition of Dana's *System*. As shown by Lacroix [6] and also by the writer,[7] collophane contains calcium carbonate in appreciable amounts. The formula may be written $3Ca_3\ (PO_4).nCa(CO_3,F_2,SO_4,O)\ (H_2O)x$, where n is indefinite and varies from 1 to 2, and x is also variable.[8]

Recently Frondel [9] has expressed the opinion that collophane is a "fine-grained meta-colloidal apatite," since the X-ray diffraction pattern is practically identical with that of apatite. The writer was well aware by 1924 (the date of his paper on fossil bone [10]) that collophane gives the X-ray pattern of apatite;[11] but he is of the opinion that something more than the X-ray pattern must be taken into account in the description and definition of mineral substances.

There have been two opposing views as to the nature of the substance called "collophane": (1) That collophane is a distinctive mineral which should be separated from apatite;[12] and (2) That collophane is a variety of fine-grained, isotropic apatite.[13]

A third point of view, now held by the writer, is that collophane is a mineraloid rather than a mineral proper.[14] It is not, then, a definite mineral species in the sense that apatite and dahllite are, but a mineral-like substance which is to all intents and purposes amorphous, even though it gives an X-ray pattern. To this class of substances Niedźwiedzki [15] applied the useful term "mineraloid."

MICROSCOPIC EXAMINATION OF THE PHOSPHORITE

Figure 4 is a photomicrograph of a typical area in a thin section of the pellet phosphorite. This section shows some of the detrital minerals, which include quartz, untwinned feldspar, plagioclase feldspar, a few grains of zircon, a little apatite, and other unidentified minerals. The pellets vary from almost colorless to a fairly deep yellow-brown and are isotropic. The matrix is siliceous shale. The dark spots in the matrix are yellowish brown and isotropic, and have an index of refrac-

---

[6] Lacroix, Alfred, Sur la constitution minéralogique des phosphorites françaises: Comptes Rendus de Séances de l'Acad. Sci., Paris, vol. 150, pp. 1213-1217, 1910.

[7] Rogers, Austin F. A review of the amorphous minerals: Jour. Geology, vol. 25, pp. 530-531, 1917.

[8] Rogers, Austin F., Collophane, a much neglected mineral: Am. Jour. Sci., vol. 3, p. 276, 1922.

[9] Frondel, Clifford, Mineralogy of the calcium phosphates in insular phosphate rock: Am. Mineralogist, vol. 28, pp. 219-220, 1943.

[10] Rogers, Austin F., Mineralogy and petrography of fossil bone: Geol. Soc. America Bull., vol. 35, pp. 535-556, 1924.

[11] Oral communication from Dr. Paul F. Kerr, 1924.

[12] See references, footnotes 7, 8, and 10.

[13] Frondel, Clifford, op. cit.

[14] Rogers, Austin F., Introduction to the study of minerals, 3d ed., pp. 208-209, 416-417, New York, 1937.

Rogers. Austin F., and Kerr, Paul F., Optical mineralogy, 2d ed., pt. II, p. 226, New York, 1942.

[15] Niedźwiedzki, J. Zur mineralogischen Terminologie: Centralblatt f. Min., Geol., u. Pal., 1909, pp. 661-663.

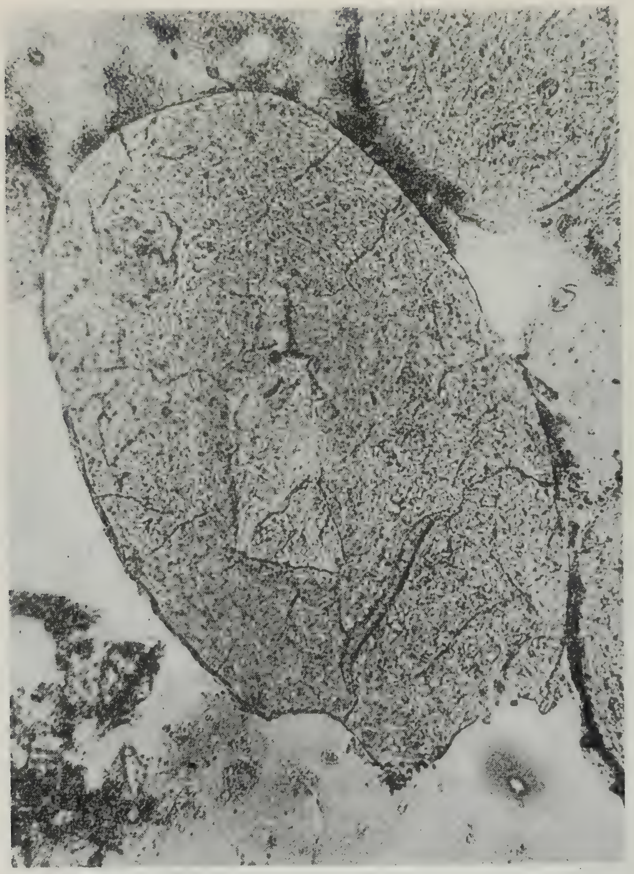


FIG. 5. (× 240) Thin section of pellet in pellet phosphorite of Carmel Valley with a detrital fragment near center and a section of *Coscinodiscus* near one end.

tion greater than that of the collophane. Some of them may be pseudomorphs after an unknown crystalline mineral, which has apparently been completely altered. Most of the pellet sections have no particular structure, but a few of them show imperfect concentric layers, which is not surprising in view of the great tendency of calcium phosphate to form concretions.

ORIGIN OF THE PELLETS

The pellets are probably phosphatic replacements of micro-coprolites of calcareous mud rich in organic matter, which were excreted by organisms of some kind. It is a well-known fact that calcium carbonate is easily replaced by calcium phosphate or calcium carbonophosphate.

DIATOMS IDENTIFIED IN THE PELLETS

Careful examination of the thin sections with an 8-millimeter objective reveals many diatom fragments. These were identified by Dr. G. Dallas Hanna of the Associated Oil Company and the California Academy of Sciences. The diatom genera noted by Dr. Hanna are: *Coscinodiscus, Stephanopyxis, Chaotoceras, Rhizosolenia,* and *Podosira.* Figure 5 shows a typical pellet with a detrital fragment near its center and toward one end a section of *Coscinodiscus* taken nearly normal to the disc-shaped valve, according to Dr. Hanna. At first glance the diatom frustules of this and other similar thin sections appear to have been phosphatized, but the diatom fragments consist of opal. The determination was made by dissolving the powdered pellets in dilute nitric acid and examining the residue with a polarizing microscope. By reason of the great difference between the refractive index of opal and that of the collophane, the diatoms photograph well. One of the pellets in figure 6 shows *Stephanopyxis turris,* which was also identified by Dr. Hanna in the thin section.

OTHER PHOSPHORITES IN CALIFORNIA

Phosphorites seem to be rather rare in California. The following occurrences are the only ones that have come to the notice of the writer:

(1) The mineral collection in the Division of Mines contains a small specimen (No. 10971) of phosphorite from near Yager, Humboldt County, collected by Thomas Dickerson, donated in 1889. This is a pale gray, almost white, massive rock evidently of sedimentary origin. Under the microscope it shows a sub-oolitic texture with isotropic collophane as the main constituent. Around the collophane there are rims and crusts of a weakly birefringent mineral (n=1.613$\mp$.003) with occasional minute six-sided crystals of short prismatic habit which are identified as dahllite. There is also an unidentified secondary mineral in cavities.

(2) Referring to a locality in Vaquero Canyon in Monterey County, Reed[16] says: "The phosphate occurs as more or less distorted oolitic opal shale. It is isotropic and has a refractive index near 1.60. The oolitic beds are from 4 to 6 inches thick and are continuous at least for distances of several yards. They are separated by thicker fine-grained beds, some of which contain a little collophane."

(3) North of La Panza Range in San Luis Obispo County, Reed[17] also records an occurrence of phosphate rock.

(4) The writer has collected specimens of massive gray to brown phosphorite made up largely of collophane at the Graham Brothers quarry near Lomita, Los Angeles County, and similar specimens from the Ball quarry near Walteria. The phosphorite occurs as more or less rounded pieces from 2 to 6 inches in size in the Pliocene

[16] Reed, Ralph D., Phosphate beds in the Monterey shales: Geol. Soc. America Bull., vol. 28, pp. 195-196, 1927.
[17] Op. cit.

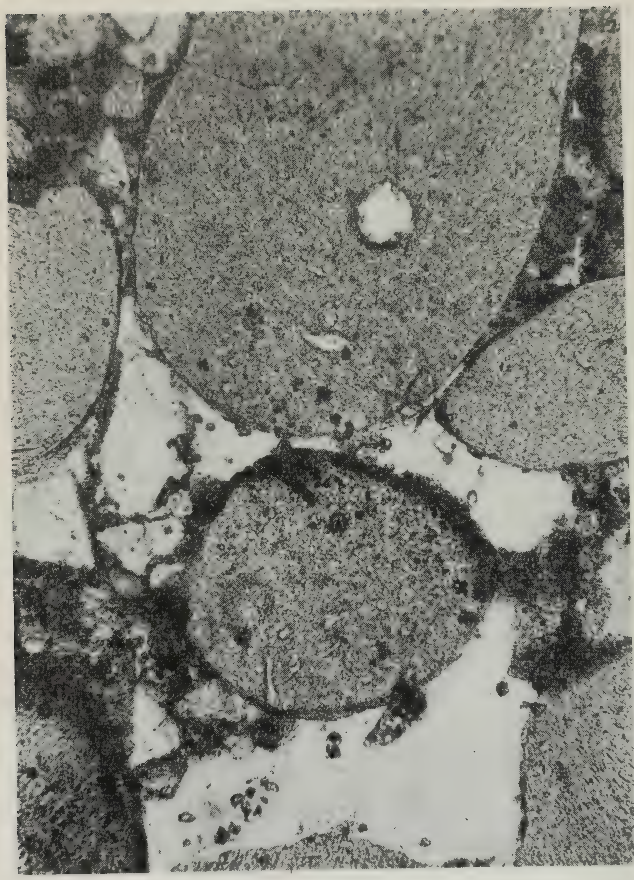


FIG. 6. (× 120) Thin section of pellets in pellet phosphorite of Carmel Valley, showing *Stephanopyxis turris* in pellet on left center, and diatom debris in the pellets.

calcarenite. This phosphorite is evidently derived from an older formation, probably the Monterey.

An examination of thin sections of the phosphorite shows structureless collophane as the dominant constituent, with a minor amount of dahllite and some detrital mineral grains and abundant fragments of diatoms and sponge spicules which consist of opal and are not phosphatized.

In all probability the phosphorite is a replacement of a calcareous or dolomitic layer in the Monterey.

(5) Tan and gray phosphorite nodules from 1 to 8 centimeters in diameter were found in drilling in upper Miocene black shale in the Playa del Rey and Torrance oil fields in the west end of the Los Angeles Basin.[18]

(6) Dietz, Emery, and Shepard[19] report the presence of extensive phosphate deposits off the coast of southern California, as revealed by dredging operations at the Scripps Institution of Oceanography. The principal mineral of the phosphatic material they determine to be collophane. The associated anisotropic mineral they say is probably francolite. They suggest that the deposits are due to direct precipitation of calcium phosphate from ocean water during the Quaternary.

ECONOMIC ASPECTS

As far as known, none of the phosphorites mentioned here are of commercial importance.

There is the possibility, however, that phosphorite or phosphate deposits of local commercial importance may be found in California.

Phosphorites are very difficult to identify in the field. They are extremely variable in appearance. Chemical tests with ammonium molybdate in a nitric acid solution will aid in the identification but the test is so delicate that it is often misleading. The best method of identifying phosphorite is by means of a polarizing microscope in either crushed fragments or thin sections.

Phosphorite has been reported[20] from fossil beds quarried on property of the Torrance Lime and Fertilizer Company on the east slope of the San Pedro Hills 2 miles southwest of Lomita, Los Angeles County.

[18] Hoots, H. W., Blount, A. L., and Jones, P. H., Marine oil shale, source of oil in Playa del Rey field, California: Am. Assoc. Petroleum Geologists, Bull. 19, p. 180, 1935.

[19] Dietz, R. S., Emery, K. O., and Shepard, F. P., Phosporite deposits on the sea floor off southern California: Geol. Soc. America Bull., vol. 53, pp. 815-848, 3 pls., 1 fig., 1942.

[20] Dietz, Emery, and Shepard, op. cit., p. 831.

Tucker, W. Burling, Los Angeles County: California Div. Mines Rept. 23, p. 328, 1927.

"In 1927 I visited the Lomita quarry which was being operated at that time and the material shipped was marl, containing nodules of phosphorite. I secured several samples of phosphorite from this quarry. At that time they were shipping the material to a compost company near Torrance." *Personal communication from W. B. Tucker, Jan. 18, 1945.*

GEOLOGY OF THE QUARTZ-CRYSTAL MINES NEAR MOKELUMNE HILL, CALAVERAS COUNTY, CALIFORNIA *

By Cordell Durrell **
U. S. Department of the Interior, Geological Survey

OUTLINE OF REPORT

ABSTRACT

The presence of quartz crystals in the Tertiary auriferous gravels of the Sierra Nevada near Mokelumne Hill has long been known. Crystals were discovered beneath Tunnel Ridge in gravels which were originally worked for gold in 1897. They were mined at that time for ornamental purposes. Twice during the present century—once during the first World War and again at a later time—the property was opened to obtain crystal for scientific purposes. The ground was opened again in 1942 and 1943 in response to the great demand for high-quality crystals for use as oscillator plates.

The quartz crystals which are present in the gravels of Tunnel Ridge Channel were transported only a relatively short distance before reaching their present position. They were probably derived from a source on the east slope of the channel near the mines rather than from a source upstream beyond the next bend in the channel. It is possible that the source vein may still exist though there is no proof that this is so. If it is still in existence it is probably on the property of the Calaveras mine. Crystals may or may not remain in the source vein if it does still exist.

The estimated reserves for the Rough Diamond Crystal mine amount to about 11,000 pounds of crystal, and for the Calaveras Crystal mine to about 6,000 pounds, a total of 17,000 pounds. There is reason to believe that more may be found. About 5 percent of the crystal is usable for electrical purposes.

INTRODUCTION

Location of the Deposit

The crystal-bearing gravels are in the SE$\frac{1}{4}$ sec. 24, and the NE$\frac{1}{4}$ sec. 25, T. 5 N., R. 11 E., M. D. They lie beneath Tunnel Ridge on the east side of Chili Gulch, $2\frac{1}{2}$ miles southeast of Mokelumne Hill, Calaveras County, California. Highway 49 passes through Chili Gulch adjacent to the property.

---

* Published by permission of the Director, Geological Survey, U. S. Department of the Interior. Manuscript submitted for publication October 31, 1944.
** Associate Geologist, Geological Survey, U. S. Department of the Interior.

FIG. 1. Index map showing location of the Calaveras and Rough Diamond crystal mines in relation to the Mother Lode (shaded area) and the counties of El Dorado, Amador, Calaveras, Sacramento, and San Joaquin.

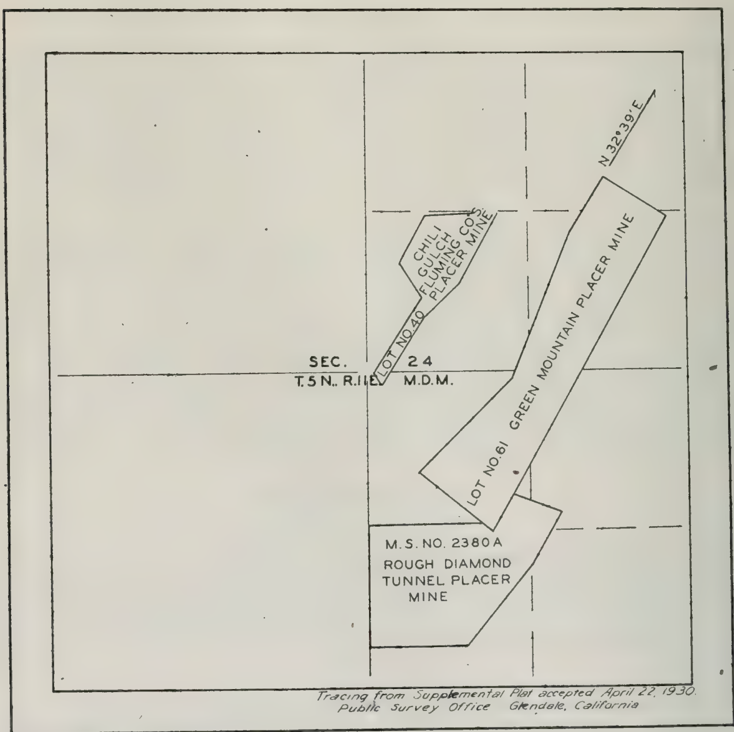


FIG. 2. Index map showing location of Green Mountain (Calaveras) and Rough Diamond claims, in sec. 24, T. 5 N., R. 11 E., M.D., Calaveras County.

History of Operations

The occurrence of crystals at this locality was first described by George F. Kunz[1] in the year of discovery, 1897. Only the location and nature of the occurrence were stated in this report, but in 1898 Kunz[2] published a short but more informative statement from which the following is quoted:

"The locality is at Mokelumne Hill, Calaveras County, and the specimens are found in the compact filling of one of the old river channels that are so marked a feature of Californian geology. Mr. John E. Burton, who is engaged in taking out the crystals, describes them as lying irregularly in every sort of position in the old filling. Some are close to the rim rock or ancient river bed, embedded in coarse colored gravel and 'cement', stained and discolored externally, but in some cases clear and brilliant within. Over the 'rim rock' is a cream-colored clay and then a coarse, wet sand, much compacted, in which are found clean, handsome-looking crystals, though all are muddy and require thorough washing. Two little 'stopes' or partly timbered drifts have been run into this deposit for several yards, and the sides, faces, and roof are seen to be full of crystals. A large number have been taken out and much more is in sight. One crystal measures 19 by 15 by 14 inches, and another 14 by 14 by 9 inches, * * *.

"It will be an interesting geological problem to ascertain the place of origin of the grand crystals now strewn in the old channels. As they are not much rolled, and lie so thickly in a limited space, it seems that they cannot be far removed from their point of occurrence, and the suggestion arises that some cavern or open vein lined with the crystals has been cut through by the ancient stream, and perhaps entirely obliterated, near the spot where they are now found."

The last published report on the crystal-bearing gravels, also by Kunz,[3] contains, in addition to a repetition of the above information, the following significant statement:

"It is claimed that twelve tons were taken out in the years 1897 and 1898; one giant crystal, surrounded by an attached cluster of 47 smaller ones, weighed over a ton. * * * There were in all some twelve tons of crystal found, but few yielded cutting material. * * *

"So far as the gravel deposit here was explored by drifts, the crystals appear to be strewn through it, and it would seem that there must be a large amount of valuable material there; but no further actual work has been done for several years."

Kunz referred to the mine in his reports of 1897 and 1905 as the "old Green Mountain mine," and it was known by that name until 1943 when the present operators named it the Calaveras Crystal mine. Apparently the property was worked for gold before the discovery of crystals. No maps of the workings or actual production records of previous operations are available today.

The mine is also known locally as the McSorley mine, after John McSorley who owned the property for many years. Adjoining the Green Mountain mine on the south, and entering the same ground, was another old drift mine, known as the Rough Diamond. The Rough Diamond mine is still the property of John McSorley, but the Calaveras Crystal mine is now owned by R. P. M. Davis, of Los Angeles, California. There are no records relative to the Rough Diamond mine, but the name was undoubtedly given because of the presence of crystals in the gravel.

Late in 1942 the Rough Diamond mine was leased from John McSorley by E. C. Setzer of South Pasadena, California, and renamed the Rough Diamond Crystal mine. Mining operations for quartz crystals

[1] Kunz, George F., Quartz and related minerals: U. S. Geol. Survey Ann. Rept. 19, pt. 6, p. 505, 1897.

[2] Kunz, George F., Quartz and related minerals: U. S. Geol. Survey Ann. Rept. 20, pt. 6, p. 587, 1898.

[3] Kunz, George F., Gems, jewelers' materials, and ornamental stones of California: California Min. Bur. Bull. 37, pp. 64-66, 1905.

were begun in September 1942 and production was first obtained in October of that year.

The Green Mountain mine was leased in 1943 from R. P. M. Davis by F. R. Zinck and a group of associates of Stockton, California, who began operations in May 1943.

Acknowledgments

The Rough Diamond Crystal mine was visited in November 1942 by Mr. Parker D. Trask of the U. S. Geological Survey who prepared a statement concerning the possibility of production. Between December 1942 and April 1943 Mr. M. N. Bramlette of the U. S. Geological Survey visited the mines several times and prepared a memorandum on them in March 1943. Thanks are due these men for their part in this work and also to Mr. Thomas P. Thayer of the U. S. Geological Survey, who, with the assistance of the present writer, prepared the first draft of the map accompanying this report. The writer wishes also to thank Mr. A. P. Busey of the Reconstruction Finance Corporation in San Francisco, for profitable discussions concerning the deposit.

Mr. E. C. Setzer and Mr. S. Menchini, operator and superintendent respectively of the Rough Diamond Crystal mine; Mr. F. R. Zinck and associates, operators of the Calaveras Crystal mine, and Mr. Mervyn Porteus, their superintendent, have given the writer much information and assistance and have extended many courtesies for which the writer is grateful.

Thanks are due to Mr. John McSorley and Mr. Thomas McSorley for information concerning the operations of earlier times.

GEOLOGY

Character of the Channel

Tunnel Ridge is composed of gravel and volcanic rocks which filled several stream channels of slightly different ages that had been cut into bedrock or into older channel fillings. The bedrock consists of slates and greenstones of the Calaveras formation. A generalized map of the complex channel system can be found in a report on this district by W. H. Storms.[4]

The filling of Tunnel Ridge Channel, which contains the crystals, is entirely gravel. This gravel is truncated, about 900 feet north of the mine workings, by a younger channel which contains only a thin section of gravel at the base. Rhyolite ash containing several thin pebble beds overlies the gravel, and this is overlain in turn by volcanic conglomerates composed of cobbles of hornblende and pyroxene andesites in a matrix of andesitic ash.

The axis of Tunnel Ridge Channel strikes about N. 70° E. where it has been opened by mining. The position of the axis in the two mines is known and the curvature, convex to the northwest as is shown on the map, is determined by the plotting of the contour lines on the bedrock surface. North of the Calaveras mine the axis swings to the east. If this course were continued, the channel would emerge on the east side of Tunnel Ridge about 400 feet east of the edge of the accompanying map. It is not present there, however, and so is presumed to swing north

[4] Storms, W. H., Ancient channel system of Calaveras County: California Min. Bur. Rept. 12, pp. 482-492, 1894.

between 600 and 900 feet northwest of the workings of the Calaveras mine, and to continue until it is truncated by the younger channel mentioned above.

The contact surface between gravel and bedrock has a gentle slope on the west side of the axis. North of the adit of the Rough Diamond mine a tributary stream entered from the northwest. North and east of the axis the slope of the bedrock surface is much steeper. The area east of the axis is convex to the northwest but is probably interrupted by a small tributary ravine just north of the most northerly workings of the Rough Diamond mine.

There is a cliff in the bedrock surface exposed about 125 feet east of the channel axis in the Calaveras mine and about 200 feet east of the axis in the Rough Diamond mine. The height of the cliff ranges from 5 to 15 feet, and the slope from nearly vertical to about 45°. The position of the cliff between the mines is not known in detail, but it seems to be convex toward the west.

The bedrock surface above the cliff is little known but it crops out on the east side of Tunnel Ridge between 500 and 600 feet east of, and between 120 and 160 feet higher than the mine workings.

The present gradient of the channel is about 130 feet per mile. The original gradient was less than this, as the present value includes the amount of tilting of the Sierra Nevada since the deposition of the gravels. Since the regional tilting was less than the present gradient, the stream must have flowed from northeast to southwest.

The area over which crystals have been found is east of the axis of the channel and is on the inside of the bend in the stream course.

The Gravels

The gravels of Tunnel Ridge Channel are 285 feet in thickness and 1,200 feet in width at the mines. The lower 125 feet of gravel has a clayey and sandy matrix and is poorly indurated. The upper 150 feet has a clean sandy matrix and is well cemented. The uppermost 50 feet is so well cemented that it forms nearly vertical cliffs along both sides of Tunnel Ridge.

Nowhere within the mines is the gravel exposed more than 10 to 15 feet above the bedrock at any one place, although the difference in elevation between the lowest and highest exposures is 45 feet. The average size of cobbles in the lower 10 feet of gravel is only 5 or 6 inches, but boulders up to 3 feet in diameter are common on the bedrock surface, and a few boulders between 5 and 6 feet in diameter have been found there. Quartzite, quartz schist, and vein quartz are the most abundant rock types in the gravel within the mines, but slate, greenstone, and mica schist are common, and a few boulders of serpentine have been found. All of the boulders composed of rocks of the latter group have been altered to clay. The matrix of the gravel which was originally sandy has also been altered to clay except for those constituents composed of quartz. Cementation is absent except in a few thin layers cemented by iron oxide. With the exception of the quartz crystals and some angular slabs of greenstone and slate which are no doubt of local origin, possibly derived from the immediately adjacent cliff, all of the boulders and pebbles are well rounded. The individual gravel beds are a few inches to six feet in thickness.

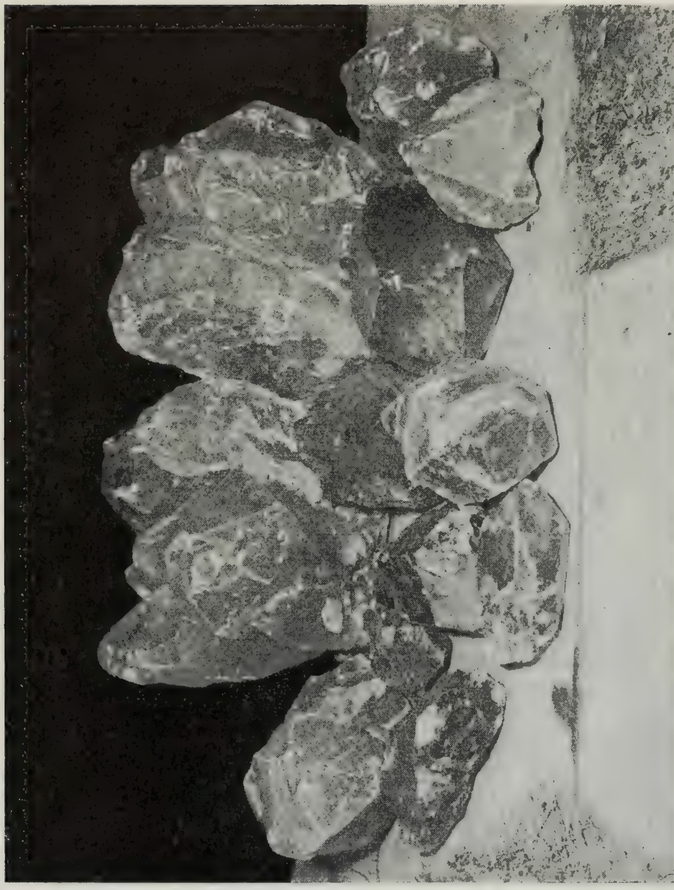


FIG. 3. Quartz crystals from the Rough Diamond Crystal mine. The two large clusters weigh more than 200 pounds each. Scale of photo, approximately 1″ = 1′. *Photo by E. C. Setzer.*

Sandy beds, a few inches to 3 feet thick, are also present in the mine workings, but they are short and usually terminate by gradation into gravel or by truncation by a cross-cutting channel. Most of the sands are composed in large part of slate fragments which have been altered to clay.

Cross bedding and cut-and-fill are so common that individual beds cannot be traced through the mines.

The gravels higher than those exposed in the mines become richer in quartz among both the pebbles and the matrix, and finer in grain at successively higher levels. Sandy beds are present here and there throughout the section.

The age of the gravels of Tunnel Ridge Channel cannot be accurately determined, but the occurrence of slates and schists in the lower part of the section suggests that they are not among the oldest of the auriferous gravels. They are, however, considerably older than the period of deposition of rhyolitic ash since the latter material occurs in the younger truncating channel on the north. The age is perhaps upper Eocene.

Distribution of Crystals

The positions of quartz crystals found during the current period of operations are shown on the map by small triangles. Not all finds have been reported but it is certain that no crystals were found west of the axis of the channel, though previously unworked gravels were penetrated in both mines on that side. The first crystal encountered in the Calaveras mine was 80 feet east of the axis of the channel, and the first found in the Rough Diamond mine was 40 feet east of the axis. Crystals were found with increasing frequency east of the first discoveries, and were present up to the base of the buried cliff in the bedrock surface. The crystals, therefore, appear to be confined to the inside of the bend in the stream course.

The width of the crystal-bearing gravel is 200 feet in the Rough Diamond mine and 70 feet in the Calaveras mine. The width probably continues to diminish to the north and east as is shown on the map. This suggests that the source of crystals is not far in that direction. The distance to the south to which crystals may occur is unknown, but it is reported that crystals have been found on the surface as much as a mile in that direction. The width of the crystal-bearing ground probably increases south of the Rough Diamond mine.

Crystals are most abundant in the lower 6 feet of gravel, but they have been found as high as 20 feet above bedrock. Close to the buried cliff they are most abundant on the bedrock surface, but to the west the greatest concentration is as much as four feet above bedrock. The crystals are not confined to any particular layer of sand or gravel. During present operations, all crystals (with the exception of one cluster, found in sand in the Calaveras mine) have been in gravel, though not confined to any single bed of gravel. In the operations of 1897 and 1898, it is reported, most of the crystals were found in sand.

Oral reports on the operations in the last century agree that crystals were not found above the cliff. The most easterly workings in the Rough Diamond mine which are above the cliff were driven to test this belief. Sixty feet of drift and two 15-foot raises were made but no crystals were found. A raise of 15 feet and a short drift from the top of it were also

run to test the gravel above the cliff in the Calaveras mine but no crystals were found. Later, however, another drift above the cliff was driven in the Rough Diamond mine only 20 to 30 feet northwest of the first one and here 10 crystals and one cluster of crystals were encountered. The highest of these was only 2 feet above bedrock, at a lower elevation than any gravel exposed in the earlier drift. The position of the bedrock in the later drift indicates that a ravine in the bedrock surface enters the main channel from the east immediately north of the drift. The configuration of the bedrock surface and the presence of crystals here indicate that some of the crystals may have been entering the main channel from the east through the ravine.

Character of the Crystals

The majority of single crystals probably weigh between 20 and 30 pounds, but several individuals weighing more than a hundred pounds each have been recovered in the present operations. Crystals under a pound in weight are not common, though broken fragments are. Kunz [5] mentions that a ''giant crystal, surrounded by an attached cluster of 47 smaller ones, weighed over a ton.'' The weight of the ''giant crystal'' alone is not stated, but men who worked in the mine at that time say that a single crystal was found that weighed more than a ton. None approaching that size has been found recently.

A number of large clusters were found during recent operations, however, and their weights ranged from about 150 to 600 pounds. Each cluster consisted of four to a dozen large crystals. The clusters are 18 to 24 inches high and have a nearly plane surface at the base, which is evidently the margin of the vein.

The crystals show very little wear. Usually less than an inch of the tip has been broken off, and less than a quarter of an inch worn from the edges. Most crystals show almost no wear on the edges, and the faces show very few impact scars. A few crystals have been worn a little on one side and not at all on the other as though they lay in the gravel in the place and position where they fell without having been turned over. The large clusters mentioned above likewise show an almost complete absence of wear.

No minerals that might give a clue to the nature of the source have been found, either attached to or enclosed within the crystals. The crystals were probably derived, however, from a large hydrothermal quartz vein similar to those which are so abundant in this part of the Sierra Nevada.

Source of the Crystals

The operators of both mines had hoped that their activities might lead to the discovery of the parent vein, but so far this has not been accomplished. Certainly the crystals have traveled only a very short distance as compared to the other materials of the gravels, but it is difficult to estimate, with any degree of certainty, how far that distance might be. If the distance of transportation was more than a few hundred yards the likelihood of discovering the vein is almost nil, for it may have been eroded away by the streams of later channels such as that to the north which is now filled with volcanic debris, or it may have been

[5] Kunz, George F., op. cit. (Bull. 37), p. 66.

removed by the modern streams, particularly by that in Old Woman Gulch which is east of Tunnel Ridge.

The general lack of wear is impressive, but, in itself, is not very helpful in this problem. The fact, however, that several large crystals were worn only slightly on one side, and not at all on the other does seem to indicate that they could have traveled but a few yards. It would seem that had they traveled evén as much as a few hundred feet they would have turned over several times, and would accordingly show some wear on all sides.

The large clusters of crystals are almost the largest single pieces of rock in the gravel, and they must have been near the maximum size that the stream could transport. They are relatively fragile and would no doubt have broken apart if they had traveled very far or had turned over even a few times. They, too, show an almost complete absence of wear. These facts suggest that the clusters could not have been transported very far, probably not more than a few score of feet.

The distribution of crystals also suggests that they have not traveled far. The crystals, being confined to the east of the axis of the channel, are on the inside of the bend in the stream course. Had they been transported from above a reverse curve in the course of the channel they would probably be found on both sides of the axis. Such a reverse curve probably occurs within 900 feet of the workings of the Calaveras mine, hence the source may have been within that distance.

The discovery of crystals above the cliff, where they are confined to a narrow zone where a ravine probably enters from the east, suggests that some of the crystals entered from that side. Since crystals are present in the main channel farther northeast they probably entered at more than one place. These facts suggest that the source of the crystals was on the east slope of the channel rather than up the stream beyond the next bend. Because of the evidently short distance of transportation, and the fact that the outcrop of the bedrock-gravel contact on the east side of Tunnel Ridge is 500 to 600 feet east of the mine workings, it is believed possible that the parent vein might be found by following the crystals above the cliff or upstream. However, it is equally likely that the source was still farther to the east and has been completely eroded away by the modern stream of Old Woman Gulch. If the source lies in that direction and if it has not been completely eroded away it is probably on the property of the Calaveras mine.

It was suggested by Kunz [6] that, could the source be found, more crystals might be obtained from it. This is possible, but it is equally possible that the supply of crystals was exhausted by the erosion which resulted in their being incorporated into the stream gravels.

MINING [7]

Both mines enter the channel from the west through drifts in the bedrock. Both adits were found to be in good condition, and they stand without timber where they are in the bedrock. Drifts in the gravel are mostly new, as the older openings were nearly all caved. Timbering is necessary in the gravels, for, although the ground is not heavy, the gravel slakes on exposure to the air.

---

[6] Kunz, George F., op. cit. (Bull. 37), p. 66.

[7] *Personal communication to the Editor*: "We expect to have our plant in operation by January 1, 1945, with a capacity of about 200 tons (20 cu. ft.) of mine run gravel per hour. This plant is located on the Calaveras Crystal mine property, a few

Explosives were used in opening the Rough Diamond mine, but were abandoned in favor of pneumatic tools when it was discovered that the crystal was being fractured. The lack of cementation in the crystal-bearing gravel, the clay matrix, and the alteration of much of the coarser material to clays permit easy working with pneumatic tools.

Drifts have been carried along in both mines mostly a foot or two above bedrock. Occasional short raises were made to test the higher gravels. The small stoped areas have been backfilled as work proceeded.

PRODUCTION AND RESERVES

Rough Diamond Crystal Mine

From the beginning of operations late in 1942 until November 1943, about 6600 pounds of crystal were recovered from the Rough Diamond Crystal mine. About 4700 cubic yards of gravel had been mined, averaging 1.4 pounds of crystal per cubic yard. The mine is still hardly beyond the development stage, and a good deal of the rock moved, which is included in the above figure, represents the penetration of barren ground in gaining access to the crystal-bearing gravel; hence the yield per cubic yard may be slightly higher in the future.

The volume of crystal-bearing gravel for a thickness of 6 feet above bedrock, and to the southern limit of mining is estimated to be 9,000 cubic yards. Applying the figure of 1.4 pounds per cubic yard to the unmined balance it is estimated that about 12,600 pounds of crystal remain to be recovered. It is not known how much farther to the south crystal may occur but additional amounts are no doubt available in that direction. Additional crystal is present higher than 6 feet above bedrock and it may be practical to extract it to a higher level. An indeterminate amount of crystal which may lie east of the buried cliff is not included in the figure above.

Calaveras Crystal Mine

About 2500 cubic yards of gravel have been mined in the present operations at the Calaveras Crystal mine, and a higher proportion of this represents barren ground penetrated in gaining access to the crystals than in the case of the Rough Diamond mine. The total amount of crystal obtained is not available, so the figure of 1.4 pounds per cubic yard obtained for the Rough Diamond mine, which is probably close to the yield for the Calaveras mine, has been applied. It is estimated that the total crystal-bearing gravel for a thickness of 6 feet above bedrock amounts to 12,000 cubic yards, of which 9,500 cubic yards remains to be mined. The reserve crystal at 1.4 pounds per cubic yard amounts to 13,300 pounds.

---

feet south and east of the tunnel portal. The plant is in general a conventional type of gravel-washing unit consisting of a 5 ft. by 35 ft. trommel, with water furnished by pumps. Mining will be done by bulldozer and power shovel.

"We propose to put all mine run material under 9 inch size through. Crystal will be recovered in the pit and from a conveyor belt. Gold will be saved in a flume equipped with heavy expanded metal over cocomat.

"From our test during the summer and fall on the Rough Diamond we have determined the necessary procedure for the reduction of mine run crystal to usable electric and optical grades. The plant now being installed is expected to operate on ratios of water to ore, and produce mine run average values in crystal and gold comparable to the determinations resulting from the work done from June 1 to November 1 of this year at the small test washing plant and laboratory on the Rough Diamond. We expect the working of both properties will require two plants. From the location of our plant we will reach the area designated as known crystal-bearing grounds quickly, by cutting across the channel with a cut of about 50 ft. bottom width." (Signed) *James F. Collins,* Chief Engineer, Quartz Crystal Products Co. December 13, 1944.

This estimate of reserves is not too reliable, however, as part of the ground included in the calculation was worked in earlier operations. The extent of these operations are not well known but can be estimated. According to oral reports by John McSorley and other parties who worked in the mines at that time, the crystals were obtained from an area south of the main drift and near the base of the cliff. A little is known about the old drifts where they have been intersected by the recent workings as shown on the map. All openings in the crystal-bearing gravel south of the main drift are east of the south-trending drift of the Calaveras mine. Oral reports indicate that they do not extend south of the southern termination as shown on the map, which is where they were first intersected in the Rough Diamond mine. If all of the gravel in this area had been mined to a height of 6 feet, which is improbable, 1600 cubic yards of gravel would have been handled. If this is deducted from the reserve estimated above at the proportion of 1.4 pounds per cubic yard, there remains a little more than 11,000 pounds of crystal.

It may be that the reserves are greater than this estimate, for it is reported that 12 tons of crystals, or about 15 pounds per cubic yard, were recovered in 1897 and 1898 from this same block of ground. Probably a higher concentration of crystals was found locally at that time than has been found in any of the recent operations, but it is possible that a similar condition might again be encountered.

QUALITY OF THE CRYSTAL

An accurate appraisal of the usability of the crystal cannot yet be made, but for radio purposes it appears to be about 5 percent, this being the ratio of crystal produced to that sold for the Rough Diamond mine. It may be somewhat higher than this, however, because the total production includes some crystal made useless by blasting during the period when the mine was being reopened, and because some of the crystal which had been rejected was later sold and cut into oscillator plates. A similar calculation for the Calaveras mine cannot be made because the total production is not known; however, there is no reason to suppose the usability to be very different than that for the crystal from the Rough Diamond mine.

Most of the common defects of quartz crystals, except solid inclusions, are present. Bubbles are common near the base and veils of bubbles are present in the upper portions of the crystals. There are often cracks, though they are generally shallow. Both electrical and optical twinning are present though neither seems to be extensively developed.

Relatively large areas of clear and unfractured quartz are available from some of the larger crystals, and some of the better material may be of optical quality. Much of the crystal that is unsuitable for electrical purposes should serve for ornamental uses and for fusing.

ROUGH DIAMOND CRYSTAL MINE
CALAVERAS CRYSTAL MINE

CALAVERAS COUNTY CALIFORNIA

SURVEY BY

THOMAS P. THAYER AND CORDELL DURRELL
DEPARTMENT OF INTERIOR GEOLOGICAL SURVEY

JUNE 1943

SCALE
0 50 100 200 300 400 FT.
CONTOUR INTERVAL 5 FEET

EXPLANATION

- 1300 ∘ POINTS ON SURFACE WITH ELEVATION
- 1354 ▲ POINTS UNDERGROUND WITH ELEVATION
- 1333 × POINTS ON THE BEDROCK-GRAVEL CONTACT WITH ELEVATION
- 7▲ OCCURRENCE OF QUARTZ CRYSTALS NUMBER REFERS TO LIST BELOW.
- PROPERTY LINE
- PROBABLE LIMIT OF CRYSTAL-BEARING GROUND
- STOPED AREAS MOSTLY FILLED
- FOOT OF RAISE OR WINZE
- HEAD OF WINZE OR RAISE
- INCLINED WINZE OR RAISE
- CONTOURS ON BEDROCK GRAVEL CONTACT SURFACE

DATUM 1300 FT ELEVATION ASSUMED FOR TOP OF RAIL AT PORTAL OF ROUGH DIAMOND MINE

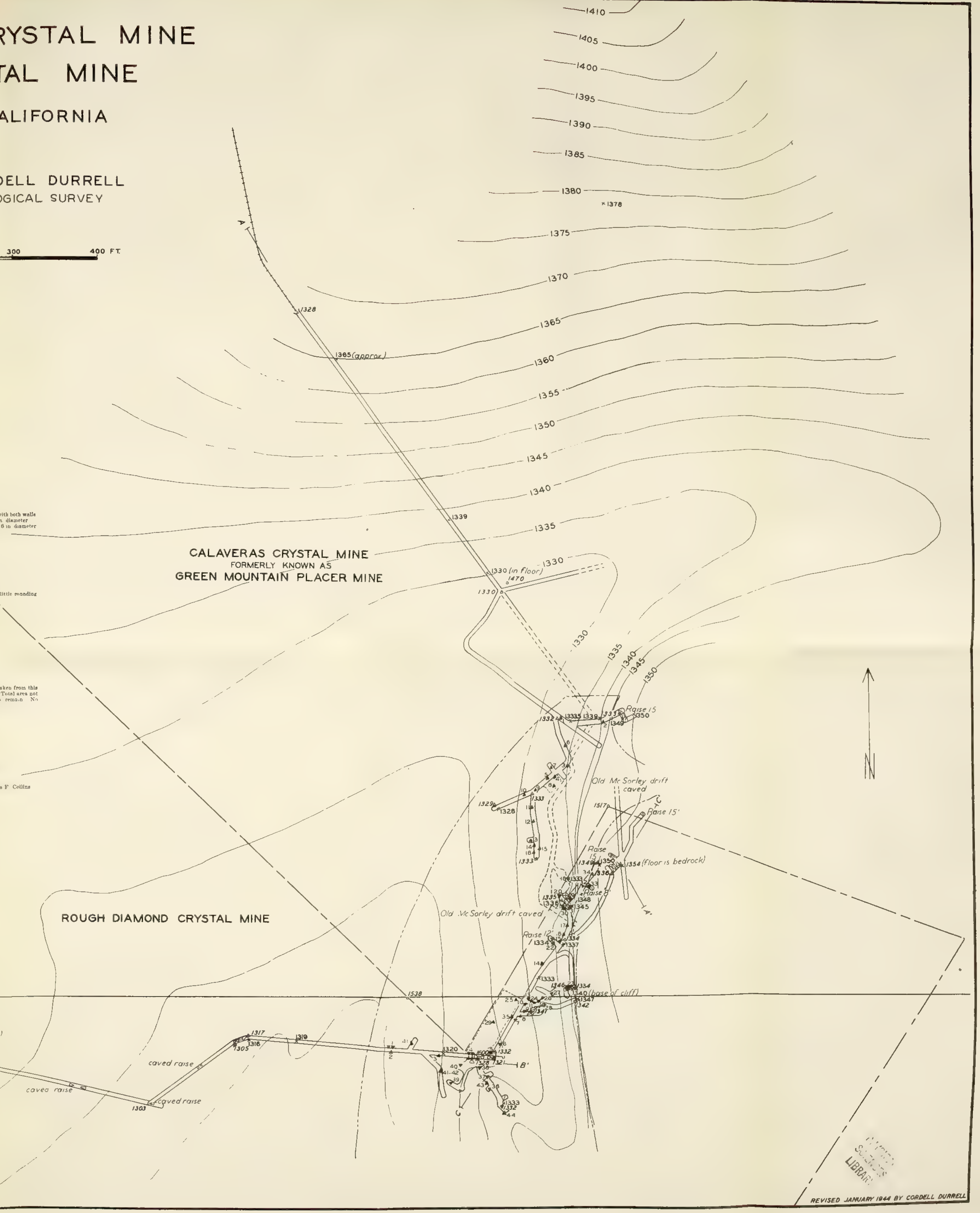
DATA ON QUARTZ CRYSTALS

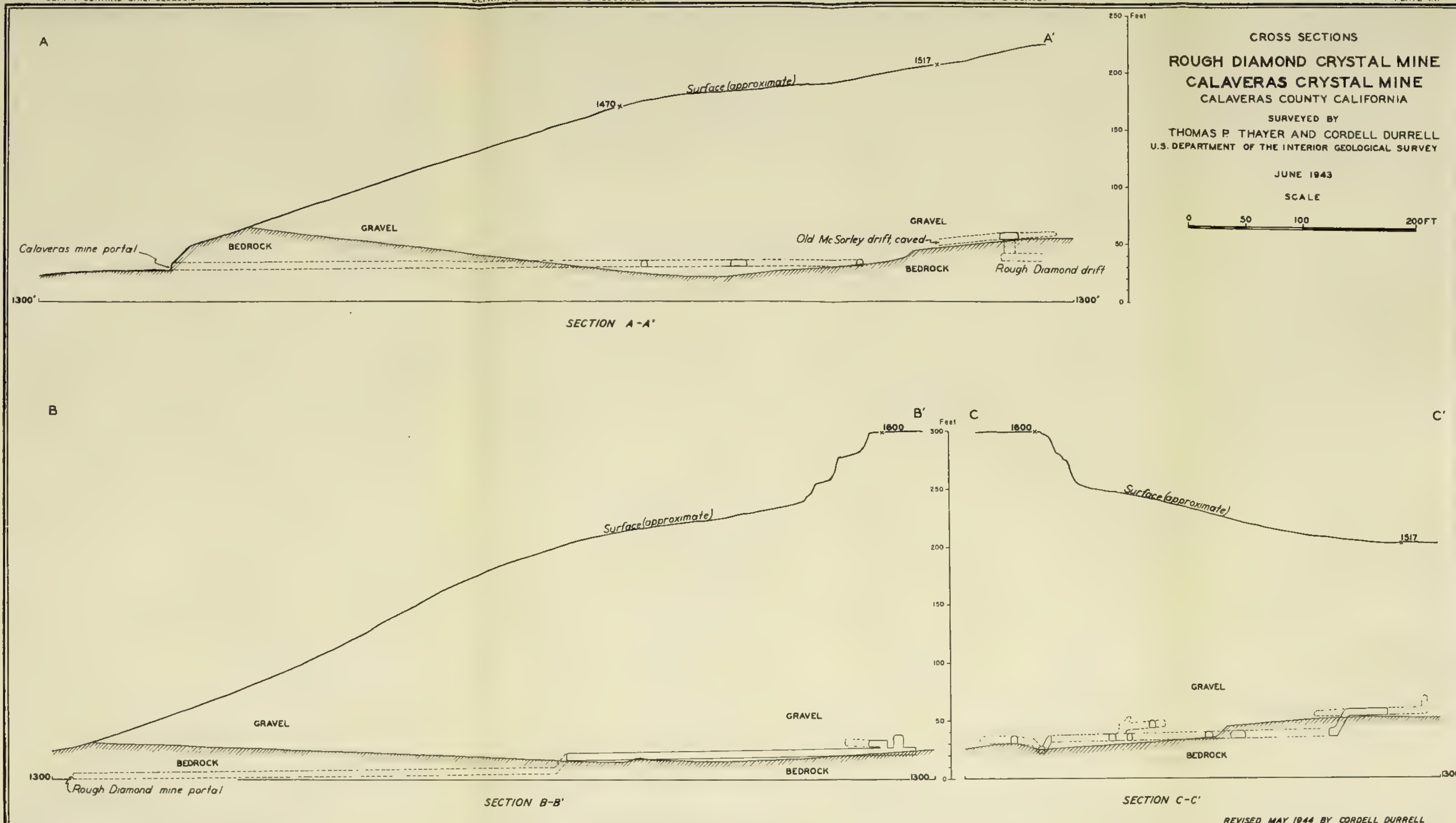
Rough Diamond Crystal Mine

Locality	Number	Size	Position	Character of Rock	Remarks
1	2		4 ft. above floor	Sandy gravel	
2	Several	Fragments	In roof	Sandy gravel	
3	1	12 in. x 18 in.		Boulder conglomerate	
4	4	12-14 lb. each		Boulder conglomerate	
5	1 cluster	600 lb. est.	4 ft. above bedrock	Boulder conglomerate	Rounded section of vein with both walls. Rough crystals up to 5 in. diameter
6	1 cluster	400 lb. est.	On floor	Boulder conglomerate	6 terminating crystals up to 6 in. diameter each
7	1	Large	In floor	Boulder conglomerate	
8	1	Large	In floor	Boulder conglomerate	
9	1	Large	In floor	Boulder conglomerate	
10	Several		Near floor	Boulder conglomerate	
11	1	12 in. long	8 ft. above main drift	Coarse gravel	
12	Several	Candles	To 18 in. above main drift	Coarse gravel	
13	Several		On floor	Boulder conglomerate	
14	1	18 lb.	1 ft. above bedrock	Boulder conglomerate	
15	Several	Small fragments	In roof	Gravel	
16	Several	Small fragments	In roof	Gravel	
17	1	4 in. slab		Coarse gravel	Broken crystal, some faces, little rounding
18	2	16-18 lb.	4.5 ft. above bedrock	Coarse gravel	
19	3	60, 3, 4 lb.	3 ft. above bedrock	Coarse gravel	
20	2	3 lb. each	5 ft. above bedrock	Coarse gravel	
21	2	Small	2 ft. above bedrock	Coarse gravel	
22	1	2-3 lb.	6 ft. above floor	Coarse gravel	
23	1	12 lb.	14 ft. above floor	Coarse gravel	Cluster of crystals
	1	Small	8 ft. above bedrock	Coarse gravel	Well worn
24	1	50 lb.	7 ft. above floor	Coarse gravel	
25	5	Large	1-5 ft. above floor	Coarse gravel	
	20	Small	Above floor	Coarse gravel	
26	1	200 lb.	On floor	Coarse gravel	Cluster of 7 crystals
	1	50-60 lb.	On floor	Coarse gravel	
27	1	Small	1-2 ft. above floor	Coarse gravel	In 2 ft. of drift
	2	Large		Coarse gravel	
28	1	50-60 lb.		Coarse gravel	
	1	112 lb.		Coarse gravel	Over 100 lb. of crystal taken from this stope up to 11/5/43. Total area not stoped. Large pillars remain. No crystals on bedrock
29	1	200 lb. cluster	From 4.5 ft. or 5 ft. above bedrock	Coarse gravel	
	Several	700 lb.		Coarse gravel	
30	1	20 lb.	In roof	Coarse gravel	
31	1	35 lb.	On bedrock	Coarse gravel	Above cliff
32	1	25 lb. cluster	On bedrock	Coarse gravel	Above cliff
33	1	10 lb.	2 ft. above bedrock	Coarse gravel	Above cliff
34	8	Large	On bedrock	Coarse gravel	Above cliff
35	1	10 lb.	10 ft. above bedrock	Coarse gravel	
36	Several	Large		Coarse gravel	
37	2	40 and 60 lb.	On bedrock	Coarse gravel	
38	1	25 lb.	On bedrock	Coarse gravel	
39	2	20 and 25 lb.	On bedrock	Coarse gravel	With numerous fragments
40	1	25 lb.	12 ft. above bedrock	Coarse gravel	
41	Several	Pieces to lbs (cracked)	Later drifts	Work done by Quartz Crystal Products Co. from June 1 to November 1, 1944 (Added to original map)	Information from James F. Collins December 12, 1944
42	1 (Well shaped)	98 lbs.	Later drifts		
43	Cluster	450 lbs.	Above top of drift		
44	Several	Pieces	Extension of drifts		

Calaveras Crystal Mine

Locality	Number	Size	Position	Character of Rock	Remarks
1	1	57 lb.	1 ft. above floor	Boulder conglomerate	Est. 15% usable
2	1	12 lb.	On bedrock	Coarse gravel	
3	1	60 lb.	2 ft. above floor	Coarse gravel	
4	1	500-600 lb.	7 ft. above floor	Coarse sand	Cluster of 7 crystals
5	1	50 lb.	1 ft. above floor	Coarse gravel	
	About 20 crystals, including 2 large clusters, recovered to 11/5/43				
6	1	20 lb.		Coarse gravel	
7	2	60 lb. total		Coarse gravel	
8	Many crystals in stope 21 ft. by 11 ft.			Coarse gravel	
9	1	20 lb.	On floor	Coarse gravel	
10	2	4 lb. each	6 ft. above bedrock	Coarse gravel	
11	2	10-12 lb. each	3 ft. above floor	Coarse gravel	
12	1	15 lb.	7 ft. above floor	Coarse gravel	
13	2	5 lb. each	3 ft. above floor	Coarse gravel	
14	1	3 lb.		Coarse gravel	
15	1	3 lb.	6 ft. above floor	Coarse gravel	
16	1	5 lb.	6 ft. above floor	Coarse gravel	




CROSS SECTIONS
ROUGH DIAMOND CRYSTAL MINE
CALAVERAS CRYSTAL MINE
CALAVERAS COUNTY CALIFORNIA
SURVEYED BY
THOMAS P. THAYER AND CORDELL DURRELL
U.S. DEPARTMENT OF THE INTERIOR GEOLOGICAL SURVEY
JUNE 1943
SCALE
0
50
100
200FT
A
A'
1470
1517
Surface (approximate)
GRAVEL
BEDROCK
Calaveras mine portal
Old McSorley drift, caved
Rough Diamond drift
1300'
SECTION A-A'
B
B'
1800
Surface (approximate)
Rough Diamond mine portal
1300
SECTION B-B'
C
C'
1517
SECTION C-C'
Feet
250
200
150
100
50
0
300
REVISED MAY 1944 BY CORDELL DURRELL

SPECIAL ARTICLES

STRATEGIC MICA [1]

By G. Richards Gwinn [2]

CONTENTS

INTRODUCTION

In modern warfare, mica is truly indispensable. Coordination of combatant units necessitates maintenance of intricate communications equipment, in the construction of which high-grade sheet mica is essential. Scrap, ground, and the poorer qualities of block mica, which are less essential to the military program, are not considered in this paper. Furthermore, as the paper is designed primarily to assist mica miners, mica derivatives, such as splittings and films, also are excluded from discussion. The paper therefore relates solely to block mica of strategic quality.

Understanding of the many factors involved in marketing mica is definitely advantageous to mica miners. The nature and detrimental effects of impurities and imperfections, the standard classification by quality, the sizes in greatest demand, and other factors relating to consumers' needs are elements with which they should be acquainted so that they may prepare their mica properly and obtain the best possible prices. Proper trimming, sizing, and classifying add greatly to the value of block mica. Improper preparation, grading, and classification are the principal reasons for the prejudice against domestic mica, although some consumers report poorer splitting qualities and lower yield in otherwise excellent mica. Heretofore our main source of strategic mica has been India, and to provide for any eventuality the United States Government has launched an extensive educational and financial-aid program to stimulate domestic production.

Most of the material in this circular has been taken from Bureau of Mines Information Circular 7219, *Marketing Strategic Mica*, by Lawrence G. Houk, to whom the writer accords full credit. However, conditions have changed so rapidly in the mica industry that considerable modification in the former paper is demanded even though it was published late in 1942.

---

[1] Reprinted from Bureau of Mines Information Circular 7258, September 1943. Revision of Inf. Circ. 7219. Figs. 1, 2, and 3, and list of *State Coordinators of Mines* have been omitted from the present reprint.

[2] Associate mineral economist, Nonmetal Economics Division, U. S. Bureau of Mines.

GOVERNMENT PROGRAM

The United States Government program to stimulate domestic production of strategic mica is conducted through the Metals Reserve Co., War Production Board, Geological Survey, and Bureau of Mines. The Geological Survey and Bureau of Mines are making a series of studies in western North Carolina, New Hampshire, Georgia, South Dakota, New Mexico, Idaho and other areas as the work progresses.

The recent streamlining of the Bureau of Mines to the present war program has included the establishment of Western, Central, and Eastern regional offices. Miners should address their inquiries to the office nearest them. These offices are: Eastern Region, College Park, Md.; Central Region, Rolla, Mo.; Western Region, Salt Lake City, Utah. Within each region are district representatives of the Bureau of Mines who will aid the miners with the many problems confronting them.

The War Production Board program is financed by the Metals Reserve Corporation (a subsidiary of the Reconstruction Finance Corporation), which has designated the Colonial Mica Corporation as its agent. This corporation, which is nonprofit, leases mining equipment, compressors, jackhammers, hoists, pumps, and supplies incident to their use at a 2 percent monthly rental (based upon cost), supervises development of mica properties, purchases strategic mica, and instructs miners in methods of trimming and grading. A 10 percent monthly rental based upon actual cost is charged for expendable or miscellaneous tools. It will also assist the miners in disposing of the noncritical grades. Domestic miners are assured markets for strategic mica at remunerative prices.

DOMESTIC CRITICAL OR STRATEGIC MICA[3]

Strategic mica, as redefined by the War Production Board on December 2, 1942, in Order M-101 as amended of that date, is block and punch mica in the rifted condition (partially or fully trimmed) that is of a quality better than black- or red-stained, free of cracks, pinholes, crossgrains, reeves, and ribs and relatively free of clay staining. It must be hard, clear, reasonably flat, and capable of being evenly and easily split into laminations or sheets of uniform thickness over the entire area, yielding sheets at least 1 by 1 inch in size. The heaviest demand at present is for sizes ranging from 1 by 1 inch to 2 by 3 inches.

The term ''strategic mica'' is much used and often misused. Possibly a better term would be ''mica of military grade,'' which would include all sizes and qualities of mica used in the manufacture of equipment for the armed forces. Strategic mica then would be the quality or sizes of which there may be a shortage at a particular time.

Contrary to popular belief in some quarters, ''ruby'' mica is not the only type wanted. Color alone is no sure criterion of value. It is true that virtually any clear ruby-colored mica will be found to have a sufficiently low power-factor loss for satisfactory use in condensers, whereas the power factor of clear mica of green or other dark colors varies from deposit to deposit. The mica from some of these deposits has a loss too high for satisfactory use in condenser films. However, there are other important strategic uses for mica that is unsuitable for condenser uses. Both block and punch micas of strategic quality prepared

[3] See glossary at end of report for definitions of terms used.

according to the customary domestic standards are wanted, and large quantities of strategic mica are needed. Punch can be utilized to best advantage for war purposes if miners will prepare it in accordance with the advice and assistance made available by the Colonial Mica Corporation. The blocks should be sound, level, with edges not shattered or opened, and as free as possible from such defects as splits, knife cuts, creases, wavy laminae, or rock punctures.

Stimulation of production of the grades and qualities of mica required for nonmilitary purposes is not part of the program of the Mica Section of the War Production Board or of the Colonial Mica Corporation. The War Production Board is confining its efforts to deposits that will produce worthwhile quantities of critical mica.

PHYSICAL PROPERTIES

A peculiar combination of physical properties (perfect cleavage, heat and electrical resistance, flexibility, and elasticity) makes mica indispensable for use in condensers, electrical generating and motive equipment, radio tubes, and certain airplane spark plugs. The forms of mica urgently needed for the war program are transmitting, receiving, and trimmer condenser films, radio-tube bridges and supports, cigarette films and nose washers for airplane spark plugs, and magneto condenser films.

Block mica must be free of structural imperfections (crossgrains, cracks, reeves, and ribs) and mineral inclusions (black or red spots, mineral stains, or streaks) to have strategic importance, because imperfections cause the mica to split unevenly, and inclusions reduce its electrical resistance and raise its power factor.

The structural imperfections that ruin otherwise good sheets of mica are designated by such descriptive terms as "ruled," "ribboned," "tangle-sheet," "herringbone," "A," "horsetail," "feather," "wedge," and "hair line." If inclusions are present, the mica may be described as (1) heavy-stained, (2) red-stained, (3) clay-stained, (4) light-dotted-stained, (5) black-spotted-stained, and (6) black-stained. Mica may be "rum," "ruby," "white," "smoky," green, light green, or silver-black in color.

Mica moderately stained with metallic oxides may be satisfactory for some dielectric uses, but mineral staining of any type renders it unfit for use in electrical condensers. The presence of numerous small air bubbles makes mica unsuitable for condenser use. Large air bells may be removed by careful splitting. Clay-staining occurs in mica only near the surface of deposits and renders it suitable only for scrap. A chemical analysis of block muscovite mica affords no indication of its commercial value or possible use.

SPECIFICATIONS

The specifications of strategic mica change frequently. Formerly, only slightly-stained was acceptable for a specific purpose; now, good-stained and even stained are being used. Some domestic mica, heavy-stained to stained according to the Indian standards, has definite strategic use because of its high degree of flexibility. (These degrees of staining are defined in a later section of this report under "classifying.") It contains no mineral inclusions, but a host of microscopic air bubbles.

The specifications vary with use. For high-grade condenser work, a low power factor is the determining element. In electrical-power generation, dielectric strength and resistance to heat are important. For "cigarette" mica used in aviation spark plugs, flexibility is one of the deciding factors. "Cigarette" mica consists of films less than 1.2 mils in thickness that can be rolled around a $\frac{1}{8}$-inch spindle without cracking or tearing and be free of pinholes and hairline cracks. Nose washers on airplane spark plugs are made of high-heat-resistant phlogopite mica. Good condenser mica should have a power factor of 0.03 percent or less. A good dielectric mica should withstand at least 1,000 volts per mil of thickness of 4 to 6 mils when tested with 2-inch plate electrodes. Almost any mica will withstand 500° to 600° without appreciable change.

ECONOMIC CONSIDERATIONS

Some mica mines produce only scrap mica suitable for grinding, but others produce scrap and variable percentages of sheet and punch. The ratio of production of sheet to punch is important to any prospective producer, as is the relationship of sizes and qualities, because profitable operation may depend on marketing considerable quantities of low-value punch.

The yield of usable block mica varies considerably in different deposits but is always small. Generally, 2 to a maximum of 6 percent of the total rock is marketable as raw block mica. A considerable part of this is salable as punch and circle mica, and a minor amount as rectangular block mica. Cobbing, rifting, and trimming eliminate 50 to 70 percent, and most of the resultant material may be the smallest size, 1 by 1 inch. Rarely more than 15 percent will be 3 by 4 inches and larger, and there is also the possibility of a large percentage of the sheets being heavy-stained or otherwise unsuitable for critical needs.

Mica mining, particularly if conducted by inexperienced operators, involves great financial risk owing to the irregularity of the borders of the pegmatites and the erratic distribution of the mica. These features dictate the size and shape of the openings and have an important bearing upon the mining method to be employed. The minimum size of shipment depends on the buyers' requirements and whether it is sold to a dealer or broker, a rifting shop, trimmer shed, or directly to a consumer. Ordinarily, mica miners have three choices in disposing of their mica: First and most commonly, they may sell their entire "mine-run" output to a trimmer shed or broker; second, they may sell the roughly graded qualities of sheet to the trimmer sheds or brokers; and third, they may prepare the mica for the consumer market. It must be recognized that the quality of mica and its degree of preparation and grading will vary from mine to mine and from time to time from the same mine; therefore, it is impossible to guarantee fixed prices for the output of any mine.

The demand for sheet mica is governed largely by activity in radio transmitting and receiving fields and in the electrical power-development field. Construction activity is a rough index of activity in ground mica. Since the Colonial Mica Corporation has come into existence, demand, prices, and marketing procedure have changed. Present demand for the strategic qualities is very large, prices are at the highest level in our history, and the purchasing program of the Colonial Mica Corporation assures the miner a good price and a ready market.

PREPARATION FOR MARKET

The proper preparation of sheet mica for sale requires judgment in eliminating minor structural imperfections and inclusions as well as knowledge and experience in trimming, splitting, cutting, grading, and classification. Grading and classification of mica are an attempt to arrive at a mean average in an endless series of variations in size and quality. The poorest quality in one classification approximately equals the best of the next inferior classification; likewise, the largest size in one grade nearly equals the smallest size of the next larger grade.

Processes of preparation include (1) cobbing or sorting, (2) rifting or sheeting, (3) trimming, (4) grading by size, and (5) classifying as to quality. These are described briefly.

Cobbing. Crystals or "books" of mica as taken from the mine are known as "mine-run," and ordinarily rock adheres to them. Cobbing is the process of removing the dirt and rock from the crystals and segregating the defective mica (scrap) from the crystals that will yield good block (cobbed mica).

Rifting. Preparation of mica by properly trained rifters is extremely important, as inexperienced workers will at best fail to recover the maximum value from the crude books and at worst can render a product virtually unusable for anything but scrap.

Rifting is splitting the cobbed mica into sheets, usually 10 to 125 mils thick. A single- or double-edged 3-inch-blade rifting knife is generally used in this operation, and its proper use involves considerable skill and experience. The products of rifting are (1) untrimmed block of mixed sizes, (2) punch and washer stock, and (3) scrap.

Care should be exercised in rifting to avoid breaking or tearing laminations at each point where the knife is inserted in the rough book. Much potentially useful mica can be spoiled or reduced in value by careless or inexperienced rifting.

Trimming. Trimming of rifted blocks to remove ragged and tangled edges may be accomplished by knife, shears, guillotine, or fingers.

In domestic practice, ragged edges are broken from the rifted block mica with the fingers (thumb trim) or are roughly trimmed with a knife so that very little usable mica is removed. The domestic practice is based upon sound experience, as the manufacturers can cut the largest pattern of specific quality from the rough-trimmed block and still have trimmings from which to produce smaller patterns of lower quality; but mica thus prepared is difficult to appraise properly, because the defective or unsound mica area is different in each piece.

Knife trimming produces a smaller quantity of uncut or unmanufactured mica and a larger percentage of scrap than thumb trim. Because of the greater proportion of waste in fabricating thumb-trimmed mica as compared with knife-trimmed blocks, its value per pound is necessarily lower.

To be of maximum value to the consumer and the producers, all strategic sheet mica should be trimmed with beveled edges. The total area of any piece of sheet mica purchased by the Colonial Mica Corporation must not be greater than 2½ times the area of the largest rectangle, free of cracks, reeves, or crossgrains, that can be cut from the piece.

Half trim mica is trimmed on two adjacent sides, with no cracks extending from the trimmed sides. *Three-quarter trim* is trimmed on

all sides, with no cracks extending from two adjacent sides and no cracks extending into the pattern. *Full trim* mica is trimmed on all sides, with all cracks, reeves, and crossgrains removed.

Care should be exercised in handling and packing high-quality block mica, as the surfaces are easily scratched and the edges readily damaged by rough handling and improper packing. It should be packed securely in wooden cases and compressed to prevent shifting during shipping. The interior of the case should be free from projecting nails and rough surfaces.

Grading. Domestic mica is graded upon the basis of the largest usable rectangle of specific quality that can be cut from the block, although the edges may be heavy-stained or otherwise defective. It is important that the sound areas only of each block be considered in determining its grade size. The sound area of specific quality within the grade rectangle must be free of cracks, pinholes, cross-grained areas, etc. Domestic grading as to size is as follows: The smallest circular size, designated as "small punch," yields disks at least 1 inch in diameter; next size is "punch," which must be large enough to yield a sound circle $1\frac{1}{2}$ inches in diameter if stained and $1\frac{1}{4}$ inches if clear. The next size is "circle," which yields disks 2 inches or more in diameter. Then follow the rectanglar sizes or combinations equal in area to $1\frac{1}{2}$ by 2 inches, 2 by 2 inches, 2 by 3 inches, 3 by 3 inches, 3 by 4 inches, 3 by 5 inches, 4 by 6 inches, 6 by 8 inches, 8 by 10 inches, and larger, known as "sheet mica." Each size includes the designated dimensions and all larger sizes up to the next grade. A sheet $4\frac{1}{2}$ by 7 inches would be classed as 4 by 6 inches. Minimum size of electrical-quality sheet mica acceptable to the trade is 2 by 2 inches.

*Use of Simplified Grading Chart.** The three concentric circles show the minimum area of small punch, punch, and circle, respectively. Place the mica so that the circle of the sound area is centered at 0 and observe the relation of the circles to this area. If it is larger than the smallest circle and smaller than the intermediate it is classed as "small punch;" if it is larger than the intermediate circle and smaller than the outer circle it is "punch," etc.

For rectangular or square blocks, place the mica so that the lower right corner of the sound area is at 0, the smaller dimension of the sound area extending along the vertical line and the larger dimension along the horizontal line. The largest rectangle on the chart that is completely within the boundaries of the sound area indicates the grade size. Each grade size includes mica of the designated minimum dimensions and smaller than the next larger size. A block or sheet the usable area of which is $1\frac{1}{2}$ by $2\frac{1}{2}$ inches is classed as $1\frac{1}{2}$ by 2 inches. Sizes 8 by 8 inches and 8 by 10 inches and larger are not shown on this chart.

In many instances it will be well for the miner to prepare a grading chart suited to his specific needs. It must be remembered that the simplified chart shows only one dimension combination for each grade size. The minimum acceptable area for 2- by 2-inch sheets is 4 square inches and the maximum is 6 square inches. The smallest or minimum dimen-

* *Ed. Note:* This chart is made as follows: "0" is in lower right-hand corner, and horizontal dimensions of rectangles are measured from "0" to the left. Horizontal dimensions are given first for each rectangle mentioned. Lay out the following rectangles with dimensions in inches: 2 x $1\frac{1}{2}$; 2 x 2; 3 x 2; 3 x 3; 4 x 3; 5 x 3; 6 x 4; 8 x 6. With "0" as center draw the following circles: 1-inch, $1\frac{1}{2}$-inch; 2-inch. Dimensions are the diameter (not the radius). *Chas. V. Averill.*

sion in this grade is 1 inch. Thus, a strip of mica 1 inch wide may range in length from 4 inches to 6 inches. The following tabulation shows the combinations of dimensions that may be used to construct a 2- by 2-inch grading chart. The series of rectangles with a common point at 0 outline the smallest acceptable and largest areas economical in the 2- by 2-inch grade.

Smallest or minimum area (4 sq. in.), inches	*Largest or maximum area (6 sq. in.), inches*
1 by 4	1 by 6
$1\frac{1}{4}$ by $3\frac{1}{4}$	$1\frac{1}{4}$ by $4\frac{3}{4}$
$1\frac{1}{2}$ by $2\frac{3}{4}$	$1\frac{1}{2}$ by 4
$1\frac{3}{4}$ by $2\frac{1}{2}$	$1\frac{3}{4}$ by $3\frac{1}{4}$
2 by 2	2 by 3
	$2\frac{1}{4}$ by $2\frac{1}{2}$

Actually, the dimensions in the column at the left outline the upper limit to the $1\frac{1}{2}$ by 2-inch grade and the lower limit of the 2- by 2-inch grade, whereas the column at the right is the upper limit of the 2- by 2-inch grade and the lower limit of the 2- by 3-inch grade. Figure 2 is constructed with the above dimensions and may be used to grade 2- by 2-inch sheets. In actual practice operators become very proficient and grade by eye without actually measuring each piece.

Colonial Mica Corporation will encourage the preparation of domestic mica of desirable qualities to full Indian standards by payment of a higher scale of prices. Miners interested in preparing their mica according to Indian standards should consult their nearest Colonial Mica Corporation field office to learn if their production is of a quality for which Indian trimming is desirable and to obtain a schedule of prices that would apply to their mica if so prepared and graded.

Classifying. Exact classification of mica for quality is extremely difficult, because it depends somewhat on individual interpretations of standards. Domestic mica is classified upon the basis of the quality of the largest usable rectangle of sound area that can be cut from the block, although the edges may be heavily stained or otherwise defective, whereas by the Indian method the average quality of the entire piece is the basis of classification; many domestic miners who have not found it worthwhile to separate their block into several qualities will now profit by doing so because of higher prices being paid for clear qualities.

The American Society for Testing Materials has adopted the following standards of quality:

Clear	Free of all mineral and vegetable inclusions, stains, air inclusions, waves, or buckles. Hard, transparent sheets.
Clear and slightly stained	Free of all mineral and vegetable inclusions, cracks, waves, and buckles, but may contain slight stains and air inclusions.
Fair-stained	Free of mineral and vegetable inclusions and cracks, hard, contains slight air inclusions, and is slightly wavy.
Good-stained	Free of mineral inclusions and cracks but contains air inclusions, some vegetable inclusions, and may be somewhat wavy.
Stained	Free of mineral inclusions and cracks but may contain considerable clay and vegetable stains and may be more wavy and softer than the better qualities.
Black-stained or spotted	Same as stained, but contains mineral inclusions.

Grading according to Indian standards limiting dimensions

Grade	Width, inches		Length, inches	
	Minimum	Maximum	Minimum	Maximum
6	0.5	1	1	2
5½	.75	1.5	1.5	3
5	1	1.7	1.7	3
4	1.5	2.5	2.5	4
3	2	3.2	3.2	5
2	2	3.7	3.7	7
1	3	4.9	4.9	8
A-1	4	6.0	6.0	9

Domestic and Indian grading (by size), approximate comparison

Usual domestic grades	Area (in single rectangle), sq. in.		Standard Indian grades
	Minimum	Maximum	
Small punch	1	1½	
Punch	1½	2½	No. 6
Circle	2½	3	No. 5½
1½ by 2 inches	3	4	—No. 5
2 by 2 inches	4	6	
2 by 3 inches	6	9	No. 4
3 by 3 inches	9	12	—No. 3
3 by 4 inches	12	15	
3 by 5 inches	15	24	No. 2
4 by 6 inches	24	36	No. 1
	36	48	No. 1 A
6 by 8 inches	48	64	Special
8 by 8 inches	64	80	Extra special
8 by 10 inches	80	96	Extra—extra special

NOTE. In domestic preparation, only approximately 20 percent of domestic "punch" may be trimmed to Indian No. 6 grade, but approximately 75 percent of the larger domestic sizes may be recovered as the corresponding Indian grades. Size 6 is divided into small, regular, and large. Small punch is equivalent to the No. 6 small.

Black-stained is sometimes separated into four qualities or classes. They are, in descending order of quality, showing increase in degree and distribution of staining: (1) heavy-stained, (2) light-dotted, (3) black-spotted, and (4) black-stained. Black-stained contains varying proportions of iron or other metallic oxide in stains, streaks, or spots.

Approximate comparison of domestic and Indian classification

Unusual domestic qualities	*Standard Indian qualities*
Strategic	
	Clear.
	Clear and slightly stained.
	Slightly stained.
	Fair-stained.
No. 1 Clear	Good-stained.
No. 2 Clear	Stained.
Nonstrategic	
No. 1 Electric	Heavy-stained.
No. 2 Electric	Light-dotted. Black-spotted.
No. 3 Electric	Black stained.

Best-quality heavy-stained is being employed for strategic purposes, and attempts are being made to utilize this type to a greater extent. The domestic clear micas, as commonly prepared, represent a mixture of qualities according to the Indian standards. Thus, the "No. 1 clear" domestic is ordinarily equivalent to a mixture of Indian qualities averaging approximately "good-stained" to "fair-stained"; "No. 2 clear" is equivalent to "stained A and B Brazilian."

PRICES

Mica is marketed in a confusing variety of sizes (grades) and classes (qualities), ranging in value from a fraction of a cent a pound for small, stained, imperfect flakes or scrap to more than $20 a pound for exceptionally large, flat, clear crystal sheets. Not only does marketable mica vary greatly in size (from small punch to 8 by 10 inches and larger), but for each grade there are at least nine different qualities, ranging from clear to black-stained. Block mica is marketed as (1) thumb-trimmed block, (2) part-trimmed block, and (3) knife- or sickle-trimmed block.

The pound (avoirdupois) is the unit upon which the price of sheet mica is based, although finished condenser films, radio-tube supports, and certain other items usually are sold by the thousand pieces. Though value is based in general upon size and quality, prices of comparable products may vary considerably, as they are usually determined by individual bargaining rather than by fixed quotations.

On December 14, 1942, the Colonial Mica Corporation was made sole buying agent for domestic strategic mica. Though value is based in general upon size and quality, the abundance or shortage of particular sizes or qualities has a decided influence upon prices. Therefore, as the price structure is so flexible, no schedule of prices is included in this publication. Colonial Mica Corporation price lists will be made available as published. It is suggested that the miner consult the nearest Colonial Mica Corporation office or field representative concern-

ing the current price schedule. A list of this corporation's offices follows:

Main office:	Colonial Mica Corporation, Dale L. Pitt, President, 141 Broadway, New York 6, New York.
Branch offices:	*New Hampshire* Orrin P. Peterson, Manager, 22 Ash Street, Newport, New Hampshire.
	North Carolina W. J. Alexander, Manager, 542 McDowell Street, Ashville, North Carolina.
	South Dakota Hubert DeBeck, Manager, Custer, South Dakota.

New Mexico
E. J. Wemlinger, Manager,
Santa Fe, New Mexico

When it is necessary for Colonial Mica Corporation to buy nonstrategic qualities, it is limited in the prices it can pay by current prices established by the Office of Price Administraton. There may be a separate ceiling for each mine or each different quality of nonstrategic mica.

Buyer and seller are equally guilty if transactions take place at above legal ceilings. Both must avoid violation of this important regulation.

PRIORITIES

It is necessary for the miner or operator to obtain a serial number for priority rating before he can purchase operating equipment. The required form must be obtained from the Mining Branch of the War Production Board. The San Francisco office is at 1355 Market Street, San Francisco 3, California.

BUYERS AND GRINDERS OF NONSTRATEGIC MICA

Illinois:

American Mica Products Co., 313 W. Chestnut St., Chicago.[1 2]
Perfection Mica Co., 2400 West Madison St., Chicago.[1 2]
U. S. Mica Manufacturing Co., 1525 Circle Ave., Forest Park.[1 2]

Massachusetts:

Huse-Liberty Mica Co., 171 Camden St., Boston.[1 2]
The Macallen Co., 61 Macallen St., Boston.[2]

New Hampshire:

General Electric Co., Bristol.[1 2]
New Hampshire Mica & Mining Co., Keene.[1 2]
E. E. Smith, Canaan.[1 2]

New York:

Brooklyn:

Ford Radio & Mica Corporation, 832 4th Ave.[1 2]
Industrial Mica Corporation, 945 64th St.[1 2]
Reliance Mica Co., 342 39th St.[2]

[1] Punch and circle.
[2] Uncut block.

New York City:

American Mica Works, 49 West St.[2]
William Brand & Co., 276 4th Ave.[1 2]
Otto Gerdau Co., 533 Canal St.[1 2]
K. & K. Mica Insulation Co., Inc., 775 Henderson Ave., West Brighton, Staton Island.[1 2]
Minerals & Insulation Corporation, 135 Price St.[2]
Eugene Munsell & Co., 200 Varick St.[1 2]
A. O. Schoonmaker Insulation Co., Inc., 635 Greenwich St.[1 2]
Heyman Co., Inc., 157 Chambers St.[1 2]
Varlacoid Chemical Co., 116 Broad St.[1 2]

North Carolina:

Asheville Mica Co., Biltmore.[1 2]
Spruce Pine Mica, Inc., Spruce Pine.[1 2]
Tar Heel Mica Co., Plum Tree.[1 2]

South Dakota:

Gladys Wells, Custer.[1 2]

Mica Grinders

Asheville Mica Co., Biltmore, N. Car.	Dry
Carolina China Clay Co., Penland, N. Car.	Do.
Concord Mica Corp., 25 Crescent St., Penacook, N. H.	Wet
English Mica Co., Spruce Pine, N. Car.	Wet, dry and micronized
Franklin Mineral Products Co., Franklin, N. Car.	Wet
Green Mountain Mica Corporation, Gassetts, Vt.	Do.
Harris Clay Co., Spruce Pine, N. Car.	Dry
Kennedy Minerals Co., Inc., 2550 E. Olympic Blvd., Los Angeles, Calif.	Do.
Mica Pulp Co., Jamestown Star Route, Boulder, Colo.	Do.
Mineral Mining Corporation, Kershaw, S. Car.	Wet
Newdale Mica Co., Erwin, Tenn.	Dry and wet
Richmond Mica Corporation, 323 S. 9th St., Richmond, Va.	Wet
Southern Mica, Johnson City, Tenn.	Dry
Thompson-Weinman, Cartersville, Ga.	Do.
U. S. Mica Mfg. Co., 1525 Circle Ave., Forest Park, Ill.	Dry
U. S. Mica Mfg. Co., E. Rutherford, N. J.	Do.
Vance, D. T., Plumtree, N. Car.	Wet
Vance-Barrett, Plumtree, N. Car.	Do.
Victor Mica Co., Spruce Pine, N. Car.	Dry
Western Nonmetallics, Inc., Pueblo, Colo.	Do.
Western Nonmetallics, Inc., 5601 S. Boyle St., Los Angeles, Calif.	Do.

Waste or scrap mica suitable for grinding may be (1) "mine-scrap" waste from mining, cobbing, and rifting sheet mica; (2) factory scrap from punching and trimming sheet; (3) byproduct mica from clay washing, kyanite, etc.; (4) mica mined exclusively for grinding and not suitable for sheet; or (5) mica schists.

U. S. BUREAU OF MINES PUBLICATIONS ON MICA

Urban, H. M., Mica-Mining Methods, Costs, and Recoveries at No. 10 and No. 21 Mines of Spruce Pine Mica Co., Spruce Pine, N. C.: Bureau of Mines Inf. Circ. 6616, 1932, 16 pp.

This paper is designed to disseminate technical information regarding the methods used. The cost tabulations represent operating expenditures only and not total costs.

---

[1] Punch and circle.
[2] Uncut block.

Inasmuch as this is the first circular concerning mica mining, some information is included with reference to the occurrence of block mica and the history of mica mining in North Carolina, together with a few notes on the physical properties and uses of the mineral and methods of processing it for use in various industries. The two mining operations described are similar, but the difference in character and value of these products affords instructive comparisons.

Horton, F. W., Mica: Bureau of Mines Inf. Circ. 6822, 1935, 56 pp., 10 ills. (Revised in 1941.)

This paper covers the salient features of the occurrence and mining of sheet mica in the United States and the preparation of mica for market; presents the results of a study of the physical properties of domestic and foreign micas, which the author hopes may be of interest to every mica user, as it definitely answers many questions as to the suitability of various micas for particular purposes; and discusses mica-trade conditions and the future outlook for the domestic mica industry.

Minerals Yearbook Chapters.

The Economics and Statistics Service of the U. S. Bureau of Mines each year prepares a résumé of the pertinent statistics of the mica industry. However, because of war restrictions, figures for 1941 and 1942 have not been released.

GLOSSARY OF TERMS

Block mica—Random thickness ⅛ inch to less than 1/100 inch (125 to 10 mils), which contains a usable area of 1½ by 2 inches minimum. The general term "block mica" is the correct designation for the more commonly used domestic form "sheet mica" in Southeastern States and "plate mica" in the New England and Western States.

Circle—Roughly, better than 2 inches in diameter, usable area.

Classification—Process of qualifying or segregating block mica as to quality. The domestic and Indian qualities are shown on pages 441-443.

- Heavy-stained—May contain minor cracks, clay and vegetable stains, but should be relatively free of mineral inclusions.
- Red-stained—Similar to the above, with red inclusions.
- Clay-stained—Inclusions of clay or mud within the laminae.
- Light-dotted-stained—May contain mineral inclusions in very small dots in segregated areas.
- Black-spotted-stained—May contain mineral inclusions in splotches; a greater area may be affected than in light-dotted, and size of the inclusions may be greater.
- Black-stained—Contains black streaks, stains, and spots; virtually entire area of sheet is affected.

(See also A. S. T. M. Standards of quality given in section on "Classifying")

Color—Clear muscovite in thin films is almost colorless. Films about 50 mils are best for judging color. "Ruby" is ruby red. Other colors need no explanation, though "smoky" commonly indicates presence of numerous microscopic air bubbles or mineral inclusions.

Dielectric—An insulating substance capable of supporting electrical stress.

Electrical mica—Heavy-stained, light-dotted, black-stained, heavy black-stained qualities.

Flat—Having a plane surface containing no ridges, waves, or ripples.

Grading—Process of sizing or segregating mica of roughly the same size into groups.

Hard—Hardness usually ranges between 2.1 and 2.5 on Mohs' scale; used here to mean solid, unweathered, and elastic.

Knife- or sickle-trimmed block — All imperfections removed may be rectangular, circular, or irregular in shape. One side should be beveled to facilitate further splitting. In circular sickle trim no large reentrant angles ("rabbit ears") should be present.

Mica — Group of complex silicate minerals of variable chemical composition; common characteristic of all is their highly developed cleavage. Muscovite, phlogopite, and biotite are the commonest varieties. This paper is concerned principally with muscovite.

Part-trimmed block — May contain minor imperfections, cracks, or punctures near the edges.

Partial films — Films of smaller area than the block from which they are split.

Power factor — Measure of loss of electrical energy in a condenser or capacitor. Condensers store electrical energy for an instant, then return it to the circuit, the loss of energy being the measure of its power factor. Power factors should be 0.02 to 0.04 percent for condensers.

Punch — Mica having usable area less than $1\frac{1}{2}$ by 2 inches. A collective term, including small punch, washer, disk, and punch.

Scrap mica — Mica so irregular in size and quality that it is suitable for grinding only. It may be (1) run-of-mine scrap, (2) factory scrap, (3) punch scrap.

Sheet — Cut or manufactured mica.

Structural imperfections — Mechanical defects caused by pressure during or subsequent to formation of crystals or intergrowths of crystals.

- A — A series of rulings or striations intersecting at about 60°.
- Cracks — Irregular separations within a crystal that may arise from blasting, rough handling, or natural causes.
- Cross grains — Breaks or tears in splitting that produce only partial films. Sometimes an intergrowth of two crystals.
- Hairlines — Irregular imperfections that are not noticeable until split into films; they cause tearing and production of partial films.
- Herringbone — Numerous rulings that intersect to form a series of V's, the legs making angles of 120° and joining at the apex to produce herringbone, horsetail, or feather structure.
- Reeves — North Carolina's term for cross-grained.
- Ribboned — Mica that splits into ribbons or long narrow strips because of parallel rulings.
- Ribs — Waves or ridges in the crystal sheets.
- Ruled — Containing planes of separation in addition to and at various angles to the cleavage plane.
- Tangle sheet — Sheets that split well in places but tear in others, producing a large percentage of partial films. Sometimes the term is applied to intergrowth of sheets.
- Wedge — Mica that, when split, yields sheets thicker on one end than on the other.

Thumb-trimmed block — Major imperfections removed; outside edges may contain mineral-stained areas, cracks, reeves, and imperfections.

ADDITIONAL NOTE ON STRATEGIC MICA

By Chas. V. Averill *

The following communications from Colonial Mica Corporation are published to furnish the reader with additional information on the strategic mica program. As Colonial Mica Corporation often changes prices and specifications, producers should communicate with that corporation for the latest information.

COLONIAL MICA CORPORATION

141 Broadway

New York, 6, New York

September 27, 1944.

To Domestic Mica Producers:

On December 31, 1944, Colonial Mica Corporation's present price commitment expires.

Upon recommendation of the War Production Board we will purchase, during the period beginning January 1, 1945 and ending March 31, 1945, at the prices set out below, only domestic mica of the following categories produced from mines other than those eliminated from our program as of January 1, 1944 by letter dated December 7, 1943:

Full trimmed domestic Muscovite ruby sheet mica, large enough to cut $1\frac{1}{2}''$ x $2''$ or larger, of first and second domestic quality	\$8.00 per pound
Domestic punch mica	.30 per pound

Please note that the above refers to ruby mica only. Such mica as green mica and black stained mica will be eliminated from our program after December 31, 1944, and sheet mica too small to cut a rectangle $1\frac{1}{2}''$ x $2''$ will not be purchased except in the form of punch mica, which will be priced at \$0.30 per pound. Please note also that sheet mica meeting the above size and quality requirements must be prepared to full trim condition, and that three-quarter trim sheet mica will not be accepted.

Present existing specifications determining quality, full trim and size will continue in effect during the period mentioned above. For your convenience these specifications are summarized in the attached "Description of Specifications."

Very truly yours,

COLONIAL MICA CORPORATION
James F. Miller, Vice President

DESCRIPTION OF SPECIFICATIONS

PUNCH — Punch mica must have a clear usable area, free from cracks, and other visible defects, of not less than 1″ in diameter and the total area of each piece must not be more than five times the usable area.

SHEET MICA

Quality: The standards of quality shall be the generally accepted trade standards.

The quality of any piece of mica shall be the quality of the largest rectangle that can be cut from the piece. The remnant area outside of the outline of the largest rectangle must be free of cracks, reeves or cross grain and must not have holes, inclusions of foreign substance, such as stone, feldspar, garnet, etc., and must be such as not to interfere with the splitting qualities of the mica.

* District Mining Engineer, California State Division of Mines, San Francisco. Manuscript submitted for publication December 19, 1944.

THICKNESS:	Minimum thickness of sheet mica shall be .007″.
SIZE:	The minimum size of sheet mica shall be such as to permit the cutting of a rectangle 1½″ wide by 2″ long or larger.
TRIM:	All sheet mica shall be fully trimmed with beveled edges. All cracks, holes, reeves or cross grains shall be trimmed out. The trimming shall follow the natural contour of the mica eliminating these defects. There shall not be more than two "V" or figure cuts on any one piece of mica and no such V cuts shall be longer than one-fourth of the width of the piece of mica measured at the point of the cut. Mica having two V cuts shall not constitute more than 10% of the weight in any one shipment.
TERMS:	F.O.B. shipping point nearest producer's rifting shop. No shipment to be made without our prior consent.

COLONIAL MICA CORPORATION

141 Broadway

New York, 6, N.Y.

October 30, 1944.

TO DOMESTIC MICA PRODUCERS:

Our circular letter of September 27th, 1944 announcing our domestic mica procurement program for the first quarter of 1945, stated, along with other provisions, that the smallest sheet mica we would buy would be sizes large enough to cut a rectangle 1½″ x 2″. It has since been deemed advisable to adjust the lower limits of the size specifications downward.

Therefore, in accordance with the War Production Board's recommendation we hereby amend our September 27th circular letter and announce that the $8.00 full trim price will apply to sheet mica having a usable rectangular area of 2½ square inches or larger provided the usable rectangle is at least one inch wide.

All other terms and specifications of our letter of September 27th remain unchanged.

Very truly yours,

COLONIAL MICA CORPORATION

JAMES F. MILLER, Vice President

MARKETING VERMICULITE [1]

By G. Richards Gwinn [2]

CONTENTS

INTRODUCTION

Vermiculites are secondary minerals formed by the alteration of biotite and phlogopite mica and are associated with basic rocks such as dunites, serpentines, and pyroxenites.

Vermiculite was first described by T. H. Webb in 1824. It remained a mineralogical curiosity until 1913, when the first commercial deposit was discovered in the Turrett mining district of Colorado. Expanded or exfoliated vermiculite was first marketed in 1915 from a deposit in this district 5 miles southeast of Hecla, Colorado. This activity was brief, but successful and continuous commercial development began in 1921 in Montana. Deposits in other States have been found and developed, but Montana is by far the largest producer. Vermiculite has also been found in South Africa, Western Australia, Russia, and Japan. Many varieties of vermiculite have been identified, because chemical composition varies widely. Various names have been assigned to them, but some of the names merely connote the locality in which the specimens were first found or the name of the finder. The commercial importance of vermiculite depends on the degree of exfoliation on rapid heating.

DESCRIPTION

The vermiculites are hydrated magnesium aluminum silicates formed by hydrothermal alteration of biotite and phlogopite mica. They retain more or less the micaceous cleavage and form soft, pliable, inelastic lamellae. The most pronounced characteristic of vermiculites is their extraordinary expansion. Upon heating the volume may increase up to 20 times the original. The question whether vermiculites are distinct minerals has puzzled mineralogists for many years, and their claim to be ranked as separate minerals has been doubted, but X-ray studies by Gruner (6)[3] and Hendricks and Jefferson (7) indicate that they constitute a specific type with a definite structure different from that of mica or chlorite.

---

[1] Reprinted from U. S. Bureau of Mines Inf. Circ. 7270, January 1944.

[2] Associate mineral economist, Nonmetal Economics Division, Bureau of Mines.

[3] Figures in parentheses refer to references in the bibliography at the end of this report.

From the tabulation of a number of analyses Gruner has shown that their average composition can be represented as 22 $MgO \cdot 5Al_2O_3 \cdot Fe_2O_3 \cdot 22SiO_2 40H_2O$. When heated, they expand, giving off considerable water. This expansion or exfoliation seems to be a mechanical disintegration of larger particles owing to the formation of steam. The increase in volume due to exfoliation varies from 6 to 20 times that of the unexpanded material, with an average of 16. So-called vermiculites containing alkalies (potassium or sodium) to an appreciable extent are probably mixtures of mica, vermiculite, and chlorite, but they retain in varying degree the exfoliating properties of true vermiculites. Seventeen varieties of vermiculite have been identified and listed by Dana (4), as follows: culsageeite, dudleyite, hallite, jefferisite, kerrite, lennilite, lucasite, maconite, painterite, pelhamite, philadelphite, protovermiculite, pyrosclerite, roseite, vaalite, vermiculite, and willcoxite. Commercially valuable deposits of only two of these have been found—vermiculite and jefferisite.

Vermiculites range in color from dark yellowish-brown to light brownish-yellow to green or bronze; hardness, 1.5; specific gravity, 2.30 to 2.80 for the unexpanded material and 0.9 for expanded vermiculite. When heated in an open tube, the color changes to a golden brown, and in the closed tube or reducing atmosphere to a silvery hue. The fusion point is 2,462° F. The total water content (free water and water of crystallization) ranges from 4 to 20 percent.

GEOLOGIC OCCURRENCE AND ORIGIN

Vermiculite is commonly associated with intrusions of ultra basic igneous rocks composed largely of pyroxene or olivine, such as dunites, serpentines, and pyroxenites. It may occur as a zone or envelope of alteration products surrounding the basic intrusion or as irregular veins within the intrusion. Quartz, feldspar, corundum, biotite, and chlorite are typical associated minerals.

In a few places it is found in almost clean or unmixed bodies large enough to mine. A few occurrences have been noted in which vermiculite is not associated with basic rocks, but the quantity of material is not large, and it does not exfoliate on heating.

As vermiculites are secondary minerals resulting from the hydrothermal alteration and weathering of biotite and phlogopite, the composition of the rocks associated with the original minerals (biotite and phlogopite) and the degree of alteration account for the variation in composition of the many varieties.

HISTORY

Vermiculite was first described by Thomas H. Webb (20) in 1824. He found the mineral in a talc deposit near Worcester, Massachusetts. It is described as follows:

> The mass has a brownish cast and is composed of two parts. The one is compact, of a dirty white and yellowish color, constituting the base; the other is in thin plates of a yellowish and blackish cast and resembles mica very much in appearance. When pulverized it seems to consist of a yellowish powder interspersed with small shining laminae. If subjected to the flame of a blowpipe or that of a common lamp it expands and shoots out into a variety of fanciful forms—resembling most generally small worms having the vermicular motion action. The vermiform remnants are composed of small irregular scales, loosely adhering to each other, having a silvery white appearance and metallic luster. If this proves to be a new variety, would it not be better in

giving it a distinctive appellation to select one that will indicate the peculiar property it possesses than to make use of an arbitrary name? I term it vermiculite (worm breeder) from vermicular, to breed or produce worms.

Jefferisite was first found in 1851 by W. W. Jefferis in a serpentine quarry near West Chester, Pennsylvania, in a vein about 2 feet wide composed of platy bronze-yellow material (1). A sample was sent to Prof. G. J. Brush, of Yale College, for analysis and identification. He identified it tentatively as a biaxial chlorite member of the hydrous magnesium silicates and thought it was vermiculite because of its exfoliating properties. In 1861, Brush decided that on the basis of its optical properties it was not vermiculite, but a new mineral, since vermiculite at that time was thought to be a uniaxial mineral (although it is now known to be biaxial with a very small axial angle). Brush proposed the name of jefferisite after Wm. W. Jefferis, of West Chester, Pennsylvania, the original discoverer (2). The properties of jefferisite, as described by Brush, are: A bronze-yellow material, optically biaxial, with a small axial angle; resembles phlogopite; exfoliates before a spirit lamp and resembles vermiculite; occurs in six-sided prisms with a micalike structure and basal cleavage; specific gravity, 2.30; hardness, 1.5.

Culsageeite was found in North Carolina in 1873 by Col. C. W. Jenks, manager of the American Corundum Co. mine near the Culsagee River in Macon County. The mineral was described by Dr. F. A. Genth and named after the Culsagee River. Culsageeite, ripidolite, and chlorite are associated as prominent gangue minerals in the corundum deposits of North Carolina and Georgia and were used as guide minerals in prospecting for corundum (5).

Nickeliferous vermiculite has been found in several dunite deposits in North Carolina. The largest showing (and it is not of commercial importance) is in the dunite body at Webster in Jackson County (12), where nickel-bearing vermiculite occurs in narrow veins in the fractured dunite. It displays a transition of colors from bright green in the nickel veins and the residual red soil of the completely weathered dunite to dark green near the contact with the fresh dunite to dark bronze in the fresh dunite.

DOMESTIC DEPOSITS

Vermiculite has been reported in eleven States in the United States, and production has come from seven. The deposits vary considerably in composition, and variations may also occur in single deposits.

Vermiculite in commercial quantities was first discovered in 1913 in Colorado. The deposits are in the Rocky Mountains in Chaffee, Fremont, Custer, and Gunnison Counties. The first find, which was of the jefferisite variety occurring as a vein 20 inches wide, was made by W. B. Thomas in the Turrett mining district in Chaffee County, 14 miles north of Salida. Because of high operating costs only a small tonnage was produced. Vermiculite was first marketed in 1915 by the Denver Mining & Manufacturing Co. from a deposit discovered in 1913 in the same mining district, about 5 miles southeast of Hecla, Chaffee County. The material was marketed under the trade name "tung ash," and was classified at that time as hydrated biotite mica of a dull brownish-black color. The crystals consist of flexible but inelastic plates, which when heated expand greatly and assume various tints of bronze (17). Production from this deposit and the other Colorado

deposits near Salida, Canyon City, Iola, and Westcliffe continued intermittently for the next 10 years.

Continuous production on a commercial scale began in 1921 from deposits in the Rainy Creek district in Lincoln County, Montana, about 7 miles east of Libby. These deposits were discovered by E. N. Alley in 1916 while prospecting for vanadium minerals. The heat from his candle or lamp caused the coarse mica-like mineral to swell and assume a golden color, and he called it "feather gold."

The deposits are on the spur north of Kearney Creek in the form of dikes striking N. 20° W. about 100 feet wide and about 2 miles long. Production is confined to pits in the most favorably mineralized zones. Complications are the presence of syenite dikes and zones of biotite incompletely altered to vermiculite. These are the largest known vermiculite deposits in the United States. The main body is on the southeastern side of the spur, and several small bodies occur on the northwestern slope. Alley and a group of associates formed the Zonolite Co., now the Universal Zonolite Insulation Co., which is by far the major producer and exfoliator of vermiculite in the United States.

Production from eastern deposits was first reported in 1929 from the Brinton quarry at West Chester, Pennsylvania, by the John Warren Watson Co. of Philadelphia. This is the locality where jefferisite was first found. Continuous production in the East began in 1933 from deposits at Ellijay (Macon County) and Swannanoa (Buncombe County), North Carolina. Deposits have also been found in Avery, Clay, and Jackson Counties. Production in Wyoming, California, Nevada, Colorado, and South Carolina has been small and intermittent, although in the past year production in South Carolina and Colorado has increased considerably.

Production figures for 1924 through 1942 follow. Although commercial production of vermiculite began in 1915, the yearly production was reported as part of the mica total or under the heading "Minerals allied to mica" until 1924.

Screened and cleaned vermiculite sold or used in the United States 1924-42

Year	*Short tons*	*Value*	*Year*	*Short tons*	*Value*
1924	2	$68	1934	4,746	$56,965
1925	102	2,818	1935	7,068	88,445
1926	150	3,750	1936	16,933	185,787
1927	51	1,318	1937	26,556	260,664
1928	1,006	38,118	1938	20,700	192,000
1929	982	24,483	1939	21,174	174,587
1930	831	13,682	1940	22,299	137,698
1931	1,256	24,758	1941	23,438	125,444
1932	1,643	16,950	1942	57,848	319,931
1933	2,247	21,993			

Prices of cleaned and screened vermiculite quoted in Metal and Mineral Markets of September 23, 1942, are per short ton f.o.b. mine, $9.50 in North Carolina and $12 in Montana. There is about 10 percent loss per ton between the raw material and the exfoliated product. Assuming an average value of $75 to $80 a ton for exfoliated and otherwise prepared vermiculite, the value of sales in 1942 would exceed $4,000,000.

FOREIGN DEPOSITS

A mineral that exfoliates when thrown into the fire was mentioned by Raphael Pumpelly in his report of a reconnaissance survey for the Japanese Government in 1865. The material was found in a body of serpentine in the mountains of the Kadzua peninsula south of Yedo (11). Tsunashirō Wada, in 1904, described a vermiculite found at Hajikano in the Province of Kai Pr., Japan, known locally as "Hiru-ishi," or leech stone (19). Vermiculite also has been found in the Ural Mountains in Russia, in the Union of South Africa and Tanganyika, Africa; and at Bulong and Kalgoorlie in the southeastern part of Western Australia.

Only the Russian and South African deposits are worked commercially. The Australian deposits are in process of development within the scope of the Australian market.

In Soviet Russia vermiculite is associated with the dunite and pyroxenite intrusions in the Ural Mountains, which are widely known as sources of platinum. Very little is known concerning the size and volume of the vermiculite deposits, but the product is marketed as loose fill and refractory bricks. Small tonnages of low-grade Russian vermiculite have been received in the United States.

Vermiculite has been reported in Tanganyika and the Union of South Africa. It was first reported in the Union from the corundum fields of northern and eastern Transvaal, where it occurs as a thin casing around the corundum reefs. Large deposits were later found in the pyroxenite and serpentine rocks of the Palaboroa region in northeastern Transvaal. In this area it seems to have been formed from phlogopite mica, which it closely resembles. It is genetically related to apatite, with which it is closely associated. Production of vermiculite in Africa began in 1938, and though small is increasing, because in addition to supplying the local market there is an export market in Great Britain.

PREPARATION AND EXFOLIATION

Vermiculite is of little use as mined, its commercial importance depending on its property of exfoliating on rapid heating. The most successful exfoliation is obtained when the material is dry, uniformly sized, and reasonably free of gangue.

Preparation

Most of the vermiculite mines in the United States are open pits, and very little blasting is necessary. The vermiculite and gangue as mined is usually sent to a crusher for preliminary separation, from which the oversize gangue goes to the waste pile and the partly crushed and cleaned vermiculite goes to the drier. The percentage of free moisture in crude vermiculite is variable, depending largely on weather conditions. The moisture is removed to facilitate grinding, screening, and sizing. The drier may be of the rotary type or the conical flash type, equipped with baffles. The charge is subjected to a heat of 200° to 300° F. for a short time. Care must be exercised to avoid temperatures high enough to disturb the combined moisture content and thereby retard full expansion. From the drier the material passes through hammer mills for separation of the vermiculite and gangue and to break up the large books of vermiculite. The hammer mill discharges to air

separators, which produce concentrates, middlings, and a tailings product. The middlings consist mainly of small thick books of vermiculite, which are returned to the hammer mill for further grinding. The separator concentrate passes to jigger screens, which classify it into the five commercial sizes—$\frac{1}{2}$-inch to +3-mesh, —3+14, —10+20, —16+24, and fines, which include all sizes that pass through the 24-mesh screen. Screening has the twofold advantage of separating the material into commercial sizes and of providing uniform sizes, assuring rapid and maximum expansion in the exfoliator. When unsized vermiculite is placed in the exfoliator, the fine material blankets the larger particles, thereby preventing their maximum exfoliation. The sized material is then bagged for shipment to the exfoliating companies, or it passes directly to the exfoliator in integrated plants.

Exfoliation

When vermiculite is brought very quickly to a red heat, it expands to a corklike consistency by the sudden expulsion of the chemically combined water, which has been changed to steam.

The properties desired in the expanded material are light weight, toughness, and complete expansion. The exfoliating properties of vermiculites vary, not only from deposit to deposit but within a single body. Some expand more than others, and the temperature at which expansion begins or reaches its maximum varies, whereas still others decrepitate when expanded. Therefore, considerable fuel or power may be saved if before using material from individual or composite sources the temperature at which the greatest exfoliation occurs while maximum toughness is retained is determined. Thus, materials from various sources may be blended properly.

Exfoliation is produced most successfully at 1,600° to 2,000° F.; the charge is subject to heat 4 to 8 seconds, followed by rapid cooling. Cooling imparts pliability and toughness to the brittle, expanded particles. Heat above the specified range drives out all the combined water in the material and renders it permanently brittle.

Several types of exfoliators are in use, and although they vary in structure, they are similar in principle. One is a modified vertical shaft furnace heated by oil-fired burners. The charge is fed into the top of the furnace and in falling is impeded by staggered baffles and, upon coming in contact with the heat from the burners, exfoliates into the characteristic accordion-like porous granules. The exfoliated material cools rapidly in its fall from the heated zone to a series of oscillating sizing screens. From the screens the sized material is carried through chutes to bins, where it is bagged for marketing. However, the expander, which is in general use, consists of a double-walled cylinder with an air space between the walls. The inner cylinder contains conical baffles that impede the fall of the sized vermiculite, which is charged in at the top of the furnace. The burners may be fired by gas or oil. The air for them has been preheated as it passes through the annular space between the two walls of the cylinder. The expanded material continues its fall from the heated zone to a flight conveyor below, which carries it to the bigger bins. The material cools rapidly in its fall from the hot zone to the conveyor. Between the conveyor and bins is an air blast, which is regulated to be strong enough to carry the light expanded material to

the bins, but against which any unexpanded vermiculite or rock drops to a screen and a chute to the waste pile.

The color of the expanded material ranges from near silver to gold, depending on conditions during expansion. A reducing atmosphere induces the silver color. Because of its light weight and consequent bulk, it is impracticable to ship expanded vermiculite far. Therefore, expanding plants have been established at market centers to process the cleaned and screened material.

USES

The low specific gravity, comparatively high refractoriness, low thermal conductivity, freedom from deterioration, and a weight of only 6 to 8 pounds per cubic foot make vermiculite suitable for thermal and acoustic insulation. Until recently, this material has been used principally as "loose-fill" insulation for dwellings. However, many new uses have been found, and in 1942 the chief one was as lightweight aggregate in the manufacture of concrete.

In loose, granular form, vermiculite is used extensively as a fill insulation in the walls and roofs of dwellings, industrial buildings, furnaces, ovens, and refrigerators. It is also used in thermal jugs, as filling in life preservers, and as a loose fill in packing shells and bombs. The motion picture industry uses vermiculite to imitate desert sandstorms, because it settles slowly and can be kept in the air with a comparatively light artificial wind.

Expanded vermiculite, combined with bonding materials, is fabricated into a wide variety of products, such as pipe covering, insulating blocks, refractory insulating concrete, roof fill, high temperature insulating cements, insulating and acoustical plasters, acoustical tiles, and structural roof slabs.

Vermiculite concrete is an extremely light-weight building material weighing 20 to 40 pounds per cubic foot. It has a compressive strength of 50 to 250 pounds per square inch and a thermal conductivity of 0.60 to 0.80 B.t.u. at 50° to 90° F. It is made like ordinary concrete in which expanded vermiculite of 3- to 20-mesh size is used as aggregate in place of sand, gravel, or stone. It is most commonly used as insulating roof fill, lightweight soundproofing and insulating floor fill, and insulated structural roof deck. Experiments have been completed in which precast slabs of vermiculite concrete have been used in erecting prefabricated houses. Cants, saddles, and slopes for roof drainage also may be made from this concrete. When poured around steel girders, vermiculite concrete protects them from buckling if they are exposed to prolonged, intense heat; and, because of its light weight, it greatly reduces the dead weight in building construction. Slabs and blocks of this concrete have been placed on decks and used as fire walls of tankers likely to be subjected to bombing attacks. Also, it has been specified by the Army and Navy for use on roofs of temporary and permanent buildings in defense areas.

Insulating bricks of vermiculite are being used increasingly. They are of two types—lightweight for use where structural strength is not required, and brick that may be used for building purposes. The lightweight type is made expressly to obtain the lowest possible conductivity, even though structural strength is sacrificed. Such bricks are used

largely in arches of open-hearth furnaces, where no structural strength is required and where the brick must be used repeatedly. The weight of a standard brick of this type is 24 ounces. Where strength is needed, a binder must be added that increases heat conductivity. It is impossible to combine low heat conductivity with high structural strength. The weight of the standard building brick is 33 ounces. The petroleum industry is using increasing quantities of these structural bricks on the inside walls of cracking units, where they serve as a combination refractory and insulator.

A plastic insulation made with vermiculite is used on the exterior of boilers and refinery columns for heat insulation and on the interior of automobiles and airplanes as a sound-proofing agent.

A British patent (485,512) was taken out in 1938 for a method of reinforcing granules of expanded vermiculite by coating them with liquid or molten carbonaceous material, such as tar, pitch, or asphalt, for use as lightweight aggregate for concrete and as insulating material. It is reported that a South African paint company is using vermiculite to obtain special coloration and metallic effects. An enamel made with processed vermiculite is more resistant to impact than ordinary enamel.

PRODUCERS

A. B. Stroud, Inglewood, Calif.
Alexite Engineering Co., Alexander Film Bldg., Colorado Springs, Colo.
Universal Zonolite Insulation Co., 2601 W. 107th Street, Chicago, Ill.
Mikolite Co., 1100 South Mill St., Kansas City, Kans.
Vermiculite Mining Co., 406 Thorpe Bldg., Minneapolis, Minn.
Vermiculite Corporation, Amber, Nev.
Industrial Minerals, Inc., 8 Wall Street, Asheville, N. C.
Minerals, Inc., Franklin, N. C.
Mrs. B. S. Tipton, Asheville, N.C.
George B. Coggins, Travelers Rest, S. C.
W. S. Bradley, Greenville, S. C.
Mrs. Phoebe Cox, Taylors, S. C.
Lewis and Martin Smith, Glenrock, Wyo.

EXFOLIATING PLANTS

California:

R. W. Clinger, 2510 Central St., Alameda.
Armor Laboratories, Inc., Glendale.
Gladding, McBean & Co., 2901 Los Feliz Boulevard, Los Angeles.
Hill Brothers Chemical Co., 2159 Bay St., Los Angeles.
Mission Lime Products Corporation, 841 Ducommun St., Los Angeles.
Standard Insulation Co., 6420 Avalon Boulevard, Los Angeles.

Colorado:

Gustavis Sessinghaus, Denver.
William B. Miller, 633 Copper Building, Denver.
Western Vermiculite Co., 1221 12th St., Denver.

District of Columbia:

Vermiculite Products Corporation, 3100 K St., N. W., Washington, D. C.

Illinois:

48 Insulating Products Co., Aurora.
International Vermiculite Co., Springfield.
George B. Smith Chemical Works, Springfield.
Universal Zonolite Insulation Co., 2601 West 107th St., Chicago.
Utica Hydraulic Cement Co., Utica.
F. E. Schündler & Co., Inc., 504 Rail Road St., Joliet.

Kansas:

Dodson Mfg. Co., 1463 Barwise, Wichita.

Missouri:

Mikolite Co., 1100 South Mill St., Kansas City.

Minnesota:

G. A. McArthur Co., 2387 Hampden Avenue, St. Paul.
B. F. Nelson Mfg. Co., 459 Harding St., Minneapolis.
Western Mineral Products Co., 1720 Madison St., N. E., Minneapolis.

Missouri:

C. B. R. Fitzwilliam & Co., Ltd., 907 Security St., St. Louis.
Zonolite Insulation Co., 5100 Manchester Ave., St. Louis.
Vermiculite Products, Inc., 911 Mulberry St., Kansas City.

Montana:

Robinson Insulation Co., 12 St. North & River Drive, Great Falls.

Nebraska:

Western Mineral Products Co., 2602 E. Creighton Ave., Omaha.

New Jersey:

Munn & Steel, Inc., 130 Lister Ave., Newark.

New Mexico:

Insulation Service Co., 1822 N. First St., Albuquerque.

New York:

Minerals & Insulation Corporation, 141 Spring St., New York City.

North Carolina:

Bee Tree Vermiculite Co., 8 Wall St., Asheville.
Minerals, Inc., Franklin, Ellis C. Soper.

Ohio:

Eagle Picher Lead Co., Cincinnati.
Wyodak Chemical Co., 4600 East 71 St., Cleveland.
Wyo-Lite Insulating Products, 4600 East 71 St., Cleveland.

Oklahoma:

V. S. Cook Lumber Co., Oklahoma City.

Oregon:

Fir-Tex Insulating Board Co., St. Helene.

Pennsylvania:

Hyzer and Lewellen, Southhampton.
Harbison-Walker Refractories Co., Farmers Bank Bldg., Pittsburgh.

Texas:

Mineral Products, National Bank of Commerce Bldg., San Antonio.
Vermiculite Mines & Industries, Inc., 1004 Frost Bank Bldg., San Antonio.
Mineral Products, Care Blue Diamond, 2722 Logan St., Dallas.

Utah:

Intermountain Insulation Co., 333 West First South St., Salt Lake City.

Washington:

Asbestos Supply Co., First St. at Jackson St., Seattle.
Asbestos Supply Co., South 10 Bernard St., Spokane.

Wyoming:

J. B. C. Mining Co., Wheatland.

BIBLIOGRAPHY

1. BRUSH, G. J. Ninth Supplement to Dana's Mineralogy. Am. Jour. Sci., 2d ser., vol. 31, 1856, pp. 369-370.
2. BRUSH, G. J. Contributions from the Sheffield Laboratory of Yale College, No. 10, Mineralogical Notes. Am. Jour. Sci., 2d ser., vol. 41, 1866, p. 248.
3. BUREAU OF MINES. Minerals Yearbook, Minor Nonmetals chapters, annual volumes.
4. DANA, E. S. System of Mineralogy. Descriptive Mineralogy, John Wiley & Sons, Inc., New York, 6th ed., 1892, pp. 664-668.
5. GENTH, F. A. Corundum, Its Alteration and Associated Minerals. Am. Phil. Soc., vol. 13, 1873, pp. 361-406.
6. GRUNER, J. W. The Structure of Vermiculites and Their Collapse by Dehydration. Am. Mineral, vol. 19, No. 12, 1934, pp. 557-575.
7. HENDRICKS, S. B., and JEFFERSON, M. E. Crystal Structure of Vermiculties and Mixed Vermiculite Chlorites. Am. Mineral., vol. 23, No. 12, pt. 1, 1938, pp. 851-862.
8. HUNTER, C. E., and MATTOCKS, P. W. Vermiculites of Western North Carolina and North Georgia. Tennessee Valley Authority, Geol. Bull. No. 5, 1936, pp. 1-21.
9. PARDEE, J. T., and LARSEN, E. S. Deposits of Vermiculite and Other Minerals in the Rainy Creek District Near Libby, Mont. Geol. Survey Bull. 805-B, 1929, 12 pp.
10. PRINDLE, L. M. Kyanite and Vermiculite Deposits of Georgia, Geol. Survey of Georgia, Bull. 46, 1936, pp. 41-46.
11. PUMPELLY, R. Across America and Asia. Leypoldt & Holt, New York, 1870, 454 pp.
12. ROSS, C. S., and SHANNON, E. V. Nickeliferous Vermiculite and Serpentine: Am. Mineral., vol. 11, No. 4, 1926, pp. 90-93.
13. SCHAEFFER, J. A. Mineral Wool and Vermiculite as Insulation. Ind. Eng. Chem. vol. 27, No. 11, 1935, pp. 1298-1303.
14. SCHOLES, W. A., GREAVES-WALKER, A. F., et al. The Development of Lightweight Concretes From North Carolina Vermiculites. North Carolina State College Record, vol. 41, No. 6, 1942, 69 pp.
15. SCHWELLNUS, C. M. Vermiculite Deposits in the Palaboroa Area, N. E. Transvaal. Dept. of Mines of the Union of South Africa, Geological Series Bull. 11, 1938, 27 pp.
16. STEEL, W. S. Vermiculite Production and Marketing by the Zonolite Co. Am. Inst. Min. Met. Eng. Trans., vol. 109, 1934, pp. 418-426.
17. STERRETT, D. B. Mica Deposits of the United States. Geol. Survey Bull. 740, 1923, pp. 25-26 and 50.
18. SUBAROV, N. Thermal Insulating Material from Vermiculite. Ceram. Abs., vol. 17, No. 1, 1938, p. 23.
19. WADI, T. Minerals of Japan, Tokyo, 1904, p. 116.
20. WEBB, T. H. New Localities of Tourmaline and Talc. Extract from a letter to the editor, Am. Jour. Sci., 1st ser., vol. 7, 1924, p. 55.

(PUBLIC LAW 349—78TH CONGRESS)

(CHAPTER 271—2d SESSION)

(S.1479)

AN ACT

PROVIDING FOR THE SUSPENSION OF CERTAIN REQUIREMENTS RELATING TO WORK ON TUNNEL SITES

Be it enacted by the Senate and House of Representatives of the United States of America in Congress assembled, That during the period beginning on the date of enactment of this Act and ending six months after the cessation of hostilities in the present wars as determined by proclamation of the President or concurrent resolution of the Congress, no location on the line of a tunnel run for the development of a vein or lode or for the discovery of mines, or veins or lodes not appearing on the surface, made by parties other than the owners of such tunnel, shall be considered valid because of the failure of such owners to prosecute work thereon with reasonable diligence as required by section 2323 of the Revised Statutes of the United States; and no right to undiscovered veins on the line of any such tunnel shall be considered to have been abandoned because of any failure to prosecute work thereon during such period: *Provided,* That every claimant of any such tunnel site, in order to obtain the benefits of this Act, shall file or cause to be filed in the office where the location notice or certificate is recorded, within six months from the date of this Act, a notice of his desire to hold the tunnel site claim under this Act.

Approved June 22, 1944.

AN ACT

REGULATING MINERAL, OIL AND GAS BROKERS AND SALESMEN

Chapter 749, Statutes of 1943

(Senate Bill No. 1111)

(Approved by Governor May 26, 1943)

An act to amend Section 10074 of, to add Sections 10009.5, 10023, 10024, 10025 and 11011.5 to, and to add Chapter 7, comprising Sections 10500 to 10601, to Part 1 of Division 4 of, the Business and Professions Code, relating to transactions in mineral, oil or gas property, regulating mineral, oil and gas brokers and salesmen and prescribing the powers and duties of the State Division of Real Estate with respect thereto.

The people of the State of California do enact as follows:

SECTION 1. Section 10009.5 is added to the Business and Professions Code, to read:

10009.5. "Provisions of this part relating to mineral, oil and gas brokerage" refers to the provisions of Chapters 1, 2, 6 and 7, of Part 1.

SEC. 2. Section 10023 is added to said code, to read:

10023. "Mineral, oil and gas licensee" refers to a person, whether broker or salesman licensed under Chapter 7 of this part.

SEC. 3. Section 10024 is added to said code, to read:

10024. "Mineral, oil and gas broker" refers to a person licensed as a broker under Chapter 7 of this part.

SEC. 4. Section 10025 is added to said code, to read:

10025. "Mineral, oil and gas salesman" refers to a person licensed as a salesman under Chapter 7 of this part.

SEC. 5. Chapter 7, comprising Sections 10500 to 10601, is added to Part 1 of Division 4 of said code, to read:

CHAPTER 7. MINERAL, OIL AND GAS BROKERAGE

Article 1. Scope of Regulation

10500. It is unlawful for any person to engage in the business, act in the capacity of, advertise or assume to act as a mineral, oil and gas broker or a mineral, oil and gas salesman within this State without first obtaining a mineral, oil and gas license from the division.

The commissioner may prefer a complaint for violation of this section before any court of competent jurisdiction, and the commissioner and his counsel, deputies or assistants may assist in presenting the law or facts at the trial.

It is the duty of the district attorney of each county in this State to prosecute all violations of this section in their respective counties in which the violations occur.

10501. A mineral, oil and gas broker within the meaning of this part is a person who, for a compensation, sells or offers for sale, buys, or offers to buy, lists, or solicits for prospective purchasers, or negotiates the purchase or sale or exchange of mineral, oil or gas property,

or who, for compensation, negotiates loans on mineral, oil or gas property, leases, or offers to lease, or negotiates the sale, purchase, or exchange of leases, rents, or places for rent, or collects rent or royalties from mineral, oil or gas property, for another or others.

10502. A mineral, oil and gas salesman within the meaning of this part is a natural person who for a compensation is employed by a licensed mineral, oil and gas broker to sell, or offer for sale, or to list, or to buy, or to offer to buy, or to negotiate the purchase or sale or exchange of mineral, oil or gas property, or to solicit for prospective purchasers of mineral, oil or gas property, or to negotiate a loan on mineral, oil or gas property, or to lease, or to negotiate the sale, purchase or exchange of leases, or offer to lease, rent or place for rent, any mineral, oil or gas property.

10503. Mineral, oil or gas property refers to land used for, intended to be used for, or concerning which representations are made with respect to, the mining of minerals or the extraction of oil or gas therefrom.

10504. Mineral, oil and gas broker within the meaning of this part includes any person who engages in the business of buying or leasing, or who takes an option on, mineral, oil or gas property, for the purpose of sale or resale, or lease or sublease, or assignment of a lease, or exchange, of such property or any part of such property.

10505. The provisions of this chapter do not apply to:

(a) Any person acting solely as a depositary under an oil or gas lease, or oil and gas lease, other than for purposes of sale.

(b) Any person who engages in any transaction pursuant to an order of a court of competent jurisdiction.

(c) Any person, and the officers and employees of such person, engaged in the business of drilling for or producing oil or gas, or of mining for or producing minerals.

10506. One act, for a compensation of buying or selling a mineral, oil or gas property of or for another, or offering for another to buy or sell or exchange a mineral, oil or gas property, or negotiating the purchase or sale or exchange of, or listing or soliciting prospective purchasers of mineral, oil or gas property, or negotiating a loan on or leasing or renting or placing for rent a mineral, oil or gas property, or collecting rent therefrom constitutes the person making such offer, sale or purchase, exchange or lease, or negotiating the loan, or so renting or placing for rent or collecting the rent or listing or soliciting, a mineral, oil and gas broker or salesman within the meaning of this part.

10507. (a) The provisions of this chapter, except Section 10512, do not apply to a real estate licensee while acting as such in connection with the sale, lease or exchange of real property (other than mineral, oil or gas property) or an interest therein, when the transfer of mineral, oil or gas property is purely incidental to the sale, lease or exchange of real property (other than mineral, oil or gas property).

(b) Any real estate licensee, who performs an act or engages in a transaction subject to this chapter, which act or transaction is incidental to his real estate business but not within subdivision (a), may secure a permit for such act or transaction from the commissioner without otherwise complying with the provisions of this chapter, except Section 10512. Not more than 10 permits per fiscal year may be issued under this section

to any real estate licensee. The real estate permit fee shall be paid for each permit.

10508. No person engaged in the business or acting in the capacity of a mineral, oil and gas broker or a mineral, oil and gas salesman within this State shall bring or maintain any action in the courts of this State for the collection of compensation for the performance of any of the acts mentioned in this article without alleging and proving that he was a duly licensed mineral, oil and gas broker or mineral, oil and gas salesman at the time the alleged cause of action arose.

10509. It is unlawful for any licensed mineral, oil and gas broker to employ or compensate, directly or indirectly, any person for performing any of the acts within the scope of this chapter who is not a licensed mineral, oil and gas broker, or a mineral, oil and gas salesman licensed under the broker employing or compensating him.

No mineral, oil and gas salesman shall be employed by or accept compensation from any person other than the mineral, oil and gas broker under whom he is at the time licensed.

It is unlawful for any licensed mineral, oil and gas salesman to pay any compensation for performing any of the acts within the scope of this chapter to any mineral, oil and gas licensee except through the mineral, oil and gas broker under whom he is at the time licensed.

For a violation of any of the provisions of this section, the commissioner may temporarily suspend or permanently revoke the license of the mineral, oil and gas licensee in accordance with the provisions of this part relating to hearings.

10510. It is a misdemeanor, punishable by a fine of not exceeding fifty dollars ($50) for each offense, for any person, whether obligor, escrow holder or otherwise, to pay or deliver to anyone a compensation for performing any of the acts within the scope of this chapter, who is not known to be or who does not present evidence to such payor that he is a regularly licensed mineral, oil and gas broker at the time such compensation is earned.

For a violation of any of the provisions of this section, the commissioner may temporarily suspend or permanently revoke the license of the mineral, oil and gas licensee in accordance with the provisions of this part relating to hearings.

10511. Any person acting as a mineral, oil and gas broker or mineral, oil and gas salesman without a license shall, upon conviction thereof, if a natural person, be punished by a fine of not to exceed five hundred dollars ($500), or by imprisonment in the county jail for a term not to exceed six months, or by both such fine and imprisonment in the discretion of the court; or if a corporation, be punished by a fine of not to exceed five thousand dollars ($5,000).

10512. Every officer, agent or employee of any company, and every other person who knowingly authorizes, directs or aids in the publication, advertisement, distribution or circularization of any false statement or representation concerning any mineral, oil or gas property, and every person who, with knowledge that any advertisement, pamphlet, prospectus or letter concerning any mineral, oil or gas property or any written statement that is false or fraudulent, issues, circulates, publishes or distributes the same, or causes the same to be issued, circulated, published or distributed, or who in any other respect wilfully violates or

fails, omits, or neglects to obey, observe or comply with any order, permit, decision, demand or requirement of the commissioner under the provisions of this part relating to mineral, oil and gas brokerage, is guilty of a misdemeanor, and shall be punished by imprisonment in the county jail for a term not to exceed six months, or by a fine of not to exceed five hundred dollars ($500), and, if a mineral, oil and gas licensee, he shall be held to trial by the commissioner for a suspension or revocation of his mineral, oil and gas license, as provided in the provisions of this part relating to hearings. It shall be the duty of the district attorney of each county in this State to prosecute all violations of the provisions of this section in respective counties in which the violations occur.

10513. All mineral, oil and gas licensees shall file reports with the commissioner of each act and transaction subject to this chapter undertaken by the mineral, oil and gas licensee. The report shall be filed at such times and in such manner and contain such information as may be prescribed by the commissioner by rule and regulation.

For a violation of the provisions of this section the commissioner may temporarily suspend or permanently revoke the license of a mineral, oil and gas licensee in accordance with the provisions of this part, relating to hearings.

Article 2. Licenses

10515. Application for license as mineral, oil and gas broker shall be made in writing to the commissioner. The application shall be accompanied by the mineral, oil and gas broker's examination fee and the original mineral, oil and gas broker's license fee and by the recommendation of two real estate owners of the county in which the applicant resides or has his place of business, certifying that the applicant is honest, truthful and of good reputation, and recommending that a mineral, oil and gas broker's license be granted to him.

If the applicant has resided, or has engaged in business for less than one year in the county from which the application is made, the application shall also be accompanied by the recommendation of two real estate owners of each of the counties where he has formerly resided or engaged in business during this period of one year prior to the filing of the application, certifying that the applicant is honest, truthful and of good reputation and recommending that a license be granted to the applicant.

10516. Application for license as mineral, oil and gas salesman shall be made in writing to the commissioner. The application shall be signed by the applicant and shall set forth the period of time during which he has been engaged in the business, stating the name of his last employer and the name and place of business of the person then employing him, or in whose employ he is to enter. The application shall be accompanied by the mineral, oil and gas salesman's examination fee and the original mineral, oil and gas salesman's license fee and by the recommendation of his employer, if employed, certifying that the applicant is honest, truthful and of good reputation, and recommending that a mineral, oil and gas license be granted to the applicant.

10517. The commissioner may require such other proof as he may deem advisable concerning the honesty, truthfulness and good reputation of any applicant for a mineral, oil and gas license, or of the officers of any corporation, or of the members of any copartnership making such application, before authorizing the issuance of a mineral, oil and gas

license. For this purpose the commissioner may call a hearing in accordance with the provisions of this part relating to hearings.

10518. In addition to the proof of honest, truthfulness and good reputation required of an applicant for a mineral, oil and gas license, the commissioner shall ascertain by written examination that the applicant, and in case of a copartnership or corporation applicant for a mineral, oil and gas broker's license that each officer, agent or member thereof through whom it proposes to act as a mineral, oil and gas licensee, has:

(a) Appropriate knowledge of the English language, including reading, writing and spelling, and of elementary arithmetic.

(b) A fair understanding of the general purposes and general legal effect of deeds, mortgages, chattel mortgages, contracts of sale, bills of sale, liens and leases, of the elementary principles of business economics, appraisals, and the purchase, sale, renting and leasing of personal property.

(c) A general and fair understanding of the obligations between principal and agent, of the rudiments of geology relating to minerals, oils and gas, and a familiarity with methods of mineral and oil exploration and production, as well as of the provisions of this part relating to mineral, oil and gas brokerage.

10519. The commissioner may, in his discretion, waive the examination of any applicant for a mineral, oil and gas broker's license who held an unrevoked or unsuspended mineral, oil and gas license on June 30th of the preceding fiscal year as an individual broker, an officer of a corporation, or member of a copartnership.

The commissioner may, in his discretion, waive the examination of any applicant for a mineral, oil and gas salesman's license who held an unrevoked or unsuspended mineral, oil and gas salesman's license on June 30th of the preceding fiscal year and who had previously qualified by passing the written examination.

10520. No mineral, oil and gas license gives authority to do any act specified in this chapter to any person, other than the person to whom the license is issued.

10521. When a mineral, oil and gas license is issued to a corporation, if it desires any of its officers other than its president, to act under its license as a mineral, oil and gas broker, it shall procure an additional license to so employ each of such officers. When a mineral, oil and gas license is granted to a copartnership, if it desires any of its members other than the one or ones through whom it is already licensed to act as a mineral, oil and gas broker, it shall procure an additional license to so employ each of such additional members.

10522. Each officer of a corporation through whom it is licensed to act as a mineral, oil and gas broker, and each member of a copartnership through whom it is licensed to act as a mineral, oil and gas broker, is, while so employed under such license a licensed mineral, oil and gas broker, but licensed only to act as such for and on behalf of the corporation or the copartnership, as officer or member, respectively.

10523. The mineral, oil and gas licenses of both broker and salesman shall be prominently displayed in the office of the mineral, oil and gas broker.

The mineral, oil and gas salesman's license shall remain in the possession of the licensed mineral, oil and gas broker employer until canceled or until the salesman leaves the employ of the broker.

10524. Immediately upon the salesman's withdrawal from the employ of the broker, the broker shall return the salesman's license to the commissioner for cancellation. A license canceled but not suspended or revoked may be reinstated within the fiscal year upon receipt of application therefor and the fee for the reinstatement of his license.

10525. Every licensed mineral, oil and gas broker shall have and maintain a definite place of business in the State of California which shall serve as his office for the transaction of business.

No mineral, oil and gas license authorizes the licensee to do business except from the location stipulated in the mineral, oil and gas license.

Notice in writing shall be given the commissioner of change of business location of a mineral, oil and gas broker, whereupon the commissioner shall issue a new mineral, oil and gas license for the unexpired period. The change or abandonment of business location without notification to the commissioner and the issuance by him of a new mineral, oil and gas license shall automatically cancel the mineral, oil and gas license theretofore issued.

10526. If the applicant for a mineral, oil and gas broker's license maintains more than one place of business within the State he shall apply for and procure an additional license for each branch office so maintained by him. Every such application shall state the name of the person and the location of the place or places of business for which such license is desired.

The commissioner may determine whether or not a broker is doing a mineral, oil and gas brokerage business at or from any particular location which requires him to have a branch office license.

10527. Each mineral, oil and gas broker shall erect and maintain a sign in a conspicuous place on the premises to indicate that he is a licensed mineral, oil and gas broker and his name shall be clearly shown thereon. The size and place of the sign shall conform to regulations that may be adopted by the commissioner.

10528. For a violation of any of the provisions of Sections 10523, 10524, 10525 and 10527, the commissioner may temporarily suspend or permanently revoke the license of the mineral, oil and gas licensee in accordance with the provisions of this part relating to hearings.

Article 3. Bonds

10540. Every mineral, oil and gas licensee shall file and maintain with the commissioner a bond in the penal sum of five thousand dollars ($5,000), issued by an admitted, corporate surety insurer, and running to the people of the State of California. The bond shall be conditioned that the licensee will obey all the provisions of this part relating to mineral, oil and gas brokerage, and complete compliance with all obligations assumed by him under his mineral, oil and gas license. In addition to any other remedy he may have, every person sustaining any injury for a breach of obligation may sue the surety for the recovery of any damages sustained by him. The liability of the surety shall not exceed five thousand dollars ($5,000) in the aggregate.

10541. The bond shall be continuous in form and remain in full force and effect and shall run concurrently with the license period and for any renewals thereof, as provided in Section 2852 of the Civil Code, unless terminated or canceled by action of the surety as provided by law or unless terminated or canceled as provided in this chapter.

10542. Upon the filing of notice with the commissioner by any surety of its withdrawal as surety for any licensee pursuant to Section 2851 of the Civil Code, the commissioner shall forthwith give notice to the licensee of the withdrawal which notice shall be by registered mail with request for return receipt and shall be addressed to the licensee at his main office as shown by the records of the commissioner. The license of any licensee shall be suspended upon the termination of the bond of the surety as provided in Section 2851 unless, prior to the termination, a new bond has been filed with the commissioner.

10543. A new bond may be filed at any time by the mineral, oil and gas licensee.

Article 4. Disciplinary Action

10560. Upon grounds provided in this article and the other articles of this chapter, the license of any mineral, oil and gas licensee may be revoked or suspended in accordance with the provisions of this part relating to hearings.

10561. The commissioner may, upon his own motion, and shall, upon the verified complaint in writing of any person, investigate the actions of any person engaged in the business or acting in the capacity of a mineral, oil and gas licensee, within this State, and he may temporarily suspend or permanently revoke a mineral, oil and gas license at any time if the licensee, within the immediately preceding three years, while a mineral, oil and gas licensee, in performing or attempting to perform any of the acts within the scope of this chapter, has been guilty of any of the following:

(a) Making any substantial misrepresentation.

(b) Making any false promises of a character likely to influence, persuade or induce.

(c) A continued and flagrant course of misrepresentation or making of false promises through mineral, oil and gas brokers or salesmen.

(d) Acting for more than one party in a transaction without the knowledge or consent of all parties thereto.

(e) Commingling the money or other property of his principal with his own.

(f) Any other conduct, whether of the same or a different character than specified in this section, which constitutes fraud or dishonest dealing.

10562. The commissioner may suspend or revoke the license of any mineral, oil and gas licensee, who within three years immediately preceding has done any of the following:

(a) Procured a mineral, oil and gas license, for himself or any salesman, by fraud, misrepresentation or deceit.

(b) Been convicted of a felony, knowledge of which the commissioner did not have at the time of last issuing a mineral, oil and gas license to him.

(c) Knowingly authorized, directed, connived at or aided in the publication, advertisement, distribution, or circulation of any material false statement or representation concerning his business or any mineral, oil or gas property offered for sale.

(d) Wilfully disregarded or violated any of the provisions of this part relating to mineral, oil and gas brokerage.

(e) Acted or conducted himself in a manner which would have warranted the denial of his application for a mineral, oil and gas license, or for a renewal thereof.

10563. When any mineral, oil and gas salesman is discharged by his employer for a violation of any of the provisions of this article prescribing a ground for disciplinary action, a verified written statement of the facts with reference thereto shall be filed forthwith with the commissioner by the employer and, if the employer fails to notify the commissioner as required by this section, the commissioner may temporarily suspend or permanently revoke the mineral, oil and gas license of the employer in accordance with the provisions of this part relating to hearings.

10564. The commissioner may deny, suspend or revoke the mineral, oil and gas license of a corporation as to any officer or agent acting under its mineral, oil and gas license, and the mineral, oil and gas license of a copartnership as to any member acting under its mineral, oil and gas license, without revoking the mineral, oil and gas license of the corporation or of the copartnership.

Article 5. Fees

10580. The fee for all mineral, oil and gas licenses shall at all periods of the fiscal year be the same as provided in this article. All mineral, oil and gas license fees shall be payable in advance of issuing the licenses and all examination fees shall be payable before taking the examination.

10581. All mineral, oil and gas licenses shall be issued for the fiscal year of July 1st to June 30th, inclusive, and shall expire on June 30th of each fiscal year at midnight.

10582. The definitions contained in this article are solely for the purposes of this article.

10583. An original mineral, oil and gas broker's license is a mineral, oil and gas license issued to a person who did not have a mineral, oil and gas broker's license on June 30th of the fiscal year previous to the fiscal year for which the license is issued.

10584. A renewal mineral, oil and gas broker's license is a mineral, oil and gas license issued to a person who had a mineral, oil and gas broker's license unrevoked and unsuspended on June 30th of the fiscal year previous to the fiscal year for which the renewal mineral, oil and gas license is issued.

10585. An original mineral, oil and gas salesman's license is a mineral, oil and gas license issued to a person who did not have a mineral, oil and gas salesman's or a broker's license either individually or as an officer of a corporation, or as a member of a copartnership, on June 30th of the fiscal year previous to the fiscal year for which the salesman's license is issued.

10586. A renewal mineral, oil and gas salesman's license is a mineral, oil and gas license issued to a person who had a mineral, oil and gas salesman's or a broker's license either individually or as an officer of a corporation, or as a member of a copartnership, on June 30th of the fiscal year previous to the fiscal year for which the salesman's license is issued.

10587. The amount of the mineral, oil and gas license fees prescribed for a license under this chapter is that fixed by the following provisions of this article.

10588. The original mineral, oil and gas broker's license fee is five dollars ($5). The mineral, oil and gas broker's examination fee is

fifteen dollars ($15) which examination fee covers all examinations prior to the issuance of such original broker's license.

10589. The additional temporary broker's license fee is five dollars ($5).

10590. For a renewal mineral, oil and gas broker's license, the annual fee is five dollars ($5).

10591. If the licensee is a corporation, the renewal license issued to it entitles the president thereof, on behalf of such corporation, to engage in the business of mineral, oil and gas broker without the payment of any further fee. For each officer thereof other than the president of a licensed corporation, through whom it engages in the business of mineral, oil and gas broker, the annual fee is two dollars ($2) in addition to the fee paid by the corporation.

10592. If the licensee is a copartnership, the license issued to it entitles one member only of the copartnership to engage on behalf of the copartnership in the business of mineral, oil and gas broker, which member shall be designated in the application of the copartnership for a license. For each other member of the copartnership who on behalf of the copartnership engages in the business of mineral, oil and gas broker the annual fee shall be two dollars ($2) in addition to the fee paid by the copartnership.

10593. The original mineral, oil and gas salesman's license fee is two dollars ($2). The mineral, oil and gas salesman's examination fee is seven dollars and fifty cents ($7.50), which examination fee covers all examinations prior to the issuance of an original salesman's license.

10594. The additional temporary salesman's license fee is two dollars ($2).

10595. For a renewal mineral, oil and gas salesman's license, the annual fee is two dollars ($2).

10596. For a branch office broker's license the fee is one dollar ($1).

10597. For change of name or of address of licensee on the records of the division the fee is one dollar ($1).

10598. For transfer of a salesman's license on change of employer, the fee is one dollar ($1).

10599. For a duplicate license the fee is one dollar ($1).

10600. For reinstatement of a license within the fiscal year the fee is one dollar ($1).

10601. For a real estate permit, the fee is one dollar ($1).

Sec. 6. Section 10074 of said code is amended to read:

10074. After qualifying as such, neither the commissioner nor any of the deputies, clerks or employees of the division shall be interested in any business opportunity company, business opportunity brokerage firm, cemetery business, cemetery brokerage firm, mineral, oil or gas business, mineral, oil or gas brokerage firm, real estate company or any real estate brokerage firm, as director, stockholder, officer, member, agent or employee, or act as a broker or salesman, or act as a copartner or agent for any broker or brokers, salesman or salesmen.

Sec. 7. Section 11011.5 is added to said code, to read:

11011.5. The questionnaire concerning any subdivision proposed to be sold as potential mineral, oil or gas property shall be accompanied by a filing fee of one hundred fifty dollars ($150).

SEC. 8. Any real estate licensee (as defined in Section 10014 of the Business and Professions Code) who has been licensed continuously for a period of five years preceding the effective date of this act may be granted a license as a mineral, oil and gas licensee (as defined in Section 10023 of the Business and Professions Code) without examination if he otherwise complies with and pays the fees (including the examination fee) required by Chapter 7 of Part 1, Division 4, of the Business and Professions Code and makes application to the Division of Real Estate within 90 days after this act takes effect.

MINERAL EXHIBIT AND STATISTICS

TOTAL RECORDED VALUE OF MINERAL PRODUCTION IN CALIFORNIA

By Henry H. Symons *

The following table gives the total recorded value of mineral substances produced in California, both metallic and nonmetallic, in order of importance. Reliable production records begin with various dates for various substances; for instance, the first reliable record of gold output was for 1848; of quicksilver, 1850; of borates, 1864; and of petroleum, 1875.

In many cases minerals were produced commercially for years before any production record was kept. This is true especially of minerals produced prior to 1894, when the California State Mining Bureau started to compile its own mineral statistics. Even after that time, some outputs went unnoticed for several years, but these were for the most part from experimental and isolated operations.

Several interesting facts are shown by the following chart. For example, the value of the petroleum produced in California is greater than the total value of all other mineral products of the State.

Petroleum has led all other products in value since 1908, when it first passed gold, which had held first place since 1848. Gold held second place from 1933 to 1940, but was exceeded in 1941 by cement; in 1942 by cement and natural gas; and in 1943 by several other substances. Natural gas was third (1933-1943) except in 1941 and 1942 when it was fourth, and in 1943 when it was second; in 1943 natural gas moved up to second place. Cement ranked fourth (1933-1943) except in 1941 and 1943 when it was third, and in 1942 when it was second. Miscellaneous stone ranked fifth from 1933 until 1943, when it moved up into fourth place. Other substances have shown considerable variation in importance in recent years.

The following chart has been compiled from data in Bulletin 128, *California Mineral Production and Directory of Mineral Producers for 1943,* by Henry H. Symons (in press, California State Division of Mines).

---

* Statistician and Curator, State Division of Mines. Manuscript submitted for publication November 22, 1944.

VALUE OF TOTAL RECORDED MINERAL PRODUCTION BY SUBSTANCES TO AND INCLUDING 1943

Mineral products in order of total value to 1943	Year of first recorded production	Total value to 1943	Value of 1943 output	Year of peak value	Year of peak output	Order of principal producing counties in 1943	Remarks
Petroleum	1875	$6,305,704,311	$289,323,406	1925	1929	Los Angeles, Kern, Fresno	California's output exceeded by Texas only (1941). In California the value of petroleum exceeds the total value of all other minerals.
Gold	1848	2,246,287,561	5,191,480	1852	1852	Nevada, Sacramento, Yuba	California led the nation in output for many years. During 1943 production of most mines declined.
Cement	1891	552,278,854	27,865,466	1942	1942	San Bernardino, Santa Clara, Riverside	Output passed by Pennsylvania only. (1941)
Natural gas	1888	459,978,736	28,046,729	1943	1943	Solano, Sacramento, Los Angeles	Output exceeded by Texas only. (1941)
Miscellaneous stone (sand, gravel, and crushed rock)	1893	399,854,680	21,716,223	1942	1942	Alameda, Los Angeles, Shasta	No record before 1893. First among the states in sand and gravel production. (1941)
Copper	1882	190,534,920	2,232,417	1916	1908	Siskiyou, Calaveras, Shasta	Shasta County led in output from 1897 to 1918; Plumas County 1919 to 1940.
Brick and hollow building tile	1893	162,113,218	4,368,675	1923	----	Los Angeles, Contra Costa, Riverside	
Quicksilver	1850	138,661,446	6,117,159	1943	1877	San Benito, Sonoma, Lake	Output greater than all other states.
Borates	1864	128,874,462	4,953,174	1937	1937	San Bernardino, Kern, Inyo	World's chief source.
Silver	1880	70,592,590	333,120	1921	1921	Inyo, Nevada, Calaveras	Usually by-product of other metals.
Potash	1914	69,067,308	*	1918	1943	San Bernardino	Passed by New Mexico only. (1941)
Soda (soda ash and salt cake)	1894	39,912,050	3,166,576	1943	1942	San Bernardino, Inyo, Imperial	First in the United States. (1941)
Salt	1887	38,431,833	1,695,231	1929	1942	Alameda, San Bernardino, San Diego	Most of the salt obtained from sea water by solar evaporation.
Mineral water	1887	37,958,407	814,700	1930	1930	Los Angeles, San Bernardino, Siskiyou	Represents that which is bottled for sale.
Tungsten ore	1905	36,253,592	5,910,745	1943	1943	Inyo, San Bernardino, Fresno	California led all states in 1943.
Diatomite	1889	33,567,549	*	1943	1943	Santa Barbara, Los Angeles, Monterey	First in the United States.
Granite	1887	28,866,406	148,160	1925	----	Fresno, Riverside, Placer	The use of dimension stone has decreased in recent years.
Lime	1894	24,291,890	----------	1941	1941	----------	Beginning with 1941, combined with limestone.
Coal	1861	23,398,108	*	1880	1900	Trinity	Output has almost completely stopped.
Clay (pottery)	1887	20,929,896	1,185,240	1928	1928	Kern, Amador, Riverside	Value given for crude clay; manufactured products exceed $12,000,000 annually.
Limestone	1894	20,759,168	1,378,647	1943	1943	Tuolumne, Santa Clara, El Dorado	For industrial purposes; not including that used in cement.
Magnesite	1887	19,123,080	*	1917	1917	Santa Clara, Stanislaus	Magnesite refractories are also made from magnesia made from sea water coming from Alameda and Monterey Counties.
Pyrite	1898	14,485,587	*	1909	1909	Shasta	Third in United States. (1941)
Lead	1877	14,002,145	885,827	1917	1917	Inyo, San Bernardino, Calaveras	Lead production was greatly stimulated by the war.
Chromite	1869	11,281,214	*	1918	1918	Glenn, Del Norte, San Luis Obispo	California leads all other states in output.
Zinc	1906	10,431,854	558,427	1916	1926	San Bernardino, Calaveras, Inyo	War greatly stimulated production.
Gypsum	1887	9,299,995	916,883	1943	1943	Riverside, Kern, Imperial	A marked increase in recent years owing to increased agricultural demand.
Talc and soapstone	1893	6,890,954	723,056	1943	1943	Inyo, San Bernardino, El Dorado	Second as to value and fourth as to amount in United States. (1941)
Magnesium salts	1916	6,219,134	728,065	1943	1943	San Mateo, Alameda, San Diego	Third in United States. (1941)
Silica (quartz and glass sand)	1899	5,861,336	533,434	1942	1942	Contra Costa, Monterey, Mariposa	Increasing demand for both glass sand and quartz in recent years.

Iodine	1929	5,510,157	*	1943	1943	Los Angeles	Chief source in United States.
Paving Blocks	1887	5,357,134	*	1912	1912	Sacramento	Paving blocks have almost entirely been replaced by smooth pavements.
Sandstone	1887	4,662,728	*	1903	1904	Monterey	Like other dimensioned stones, the demand has become less in recent years.
Bituminous rock	1887	4,585,162	*	1888	1910	Santa Cruz, Santa Barbara	
Iron ore	1881	4,028,462	2,341,827	1943	1943	San Bernardino, Shasta, Santa Cruz	Steel plant at Fontana started operation in 1942.
Manganese ore	1887	3,840,347	*	1918	1918	Stanislaus, Trinity, Santa Clara	Manganese production stimulated by the war.
Marble	1887	3,568,420		1909	1909	Tuolumne (in past)	Marble has been gradually replaced by artificial stone, as terrazzo.
Dolomite	1915	3,214,750	472,756	1943	1943	Monterey, San Benito, Tuolumne	A marked increase in recent years.
Bromine	1926	3,187,444	*	1943	1943	San Bernardino, Alameda, San Diego	Third in the United States. (1941)
Gem materials	1900	2,604,232	329,868	1906		Calaveras, Riverside	Includes optical minerals.
Bentonite	1899	2,591,923	118,257	1928	1928	San Bernardino, Inyo, San Diego	Ranks high among the states in total output.
Barite	1910	2,461,600	*	1929	1929	Mariposa, Nevada	California ranks fourth among the states in output. (1941)
Pumice and volcanic ash	1909	2,404,271	142,665	1941	1941	Kern, Madera, Inyo	Second in United States. (1941)
Molybdenum ore	1916	1,394,894	*	1943	1943	Inyo	Mostly a by-product from tungsten ores.
Calcium chloride	1921	1,301,335	*	1926	1926	San Bernardino, Imperial	Third in United States. (1941)
Slate	1889	1,254,134	*	1906	----	El Dorado	Early production reported in squares of slate roofing, later in tons used in granules.
Platinum group metals	1887	1,179,254	*	1941	1941	Merced, Sacramento, Trinity	Output passed only by Alaska. (1941)
Feldspar	1910	1,062,633	*	1928	1928	San Bernardino, San Diego, Fresno	
Carbon dioxide	1894	938,346	248,126	1942	1943	Imperial, Mendocino	A rapidly growing demand for dry ice.
Sillimanite-andalusite-kyanite group	1922	929,946	*	1926	1926	Mono, Imperial	
Sulphur	1865	829,399		1941	1941	Inyo, Alpine (in past)	
Lithia	1899	716,221	*	1920	1920	San Bernardino	First in United States. Recent from brines of Searles Lake.
Grinding-mill pebbles	1915	283,956	*	1916	1917	San Diego	
Mineral paint	1890	237,399	*	1899	1903	Stanislaus	
Antimony	1887	225,478		1916	1916		Unimportant and intermittent.
Strontium	1916	202,293	*	1943	1943	Imperial, San Bernardino	Second in the United States. (1941)
Asbestos	1887	162,872	*	1910	1921	Napa, Placer	
Titanium	1927	157,780	*	1928	1928	Los Angeles	Small output.
Onyx and travertine	1887	122,219		----	1894		(see Marble).
Shale oil	1922	109,500		1924	----	Santa Barbara (in past)	Production experimental only.
Mica	1902	96,974		1936	1936	Imperial (in past)	
Graphite	1901	87,495		1918	1918	Los Angeles (in past)	
Tin	1891	60,544					No output reported for years.
Serpentine	1895	33,259		1902	1895	Los Angeles (in past)	Verde antique was quarried on Catalina Island.
Calcium silicates	1933	23,854		1938	1938	Kern	First known commercial production in United States in 1933.
Cadmium	1917	9,843					Only one year reported.
Fluorspar	1917	4,622		1934	1934	San Bernardino (in 1934)	
Bismuth	1904	2,400					Only one year reported.
Arsenic	1924	1,356					Only one year reported.
Zircon	1937	1,310		1941	----	Placer	Small amount of zircon is found in most black sands.
Alum minerals	1938	160				Riverside (in past)	
Totals		$11,185,358,389	$426,445,280				

*1943 value not given so as not to revea lthe output of individual deposits.

ACCESSIONS TO THE EXHIBIT

By HENRY H. SYMONS *

The museum of the State Division of Mines possesses an exceptionally fine collection of rocks and minerals of economic and academic value. It ranks among the first five such collections in North America and contains not only specimens of most of the known minerals found in California, but much valuable and interesting material from other States and foreign countries as well.

The exhibit is daily visited by engineers, students, business men, and prospectors as well as tourists and sightseers. In addition to its practical use in the economic development of California's mineral resources, the collection is a most valuable educational asset to the State and to San Francisco.

Mineral specimens suitable for exhibit purposes are solicited, and their donation will be appreciated by the Division of Mines, as well as by those who utilize the facilities of the collection.

Among the specimens received recently and catalogued for the exhibit are the following:

21166 VOLTAITE, $3(K_2,Fe)O.(Al,Fe)_2O_3.6SO_3.9H_2O$. Crystals from walls of old stope, No. 4 level, New Idria quicksilver mine, San Benito County, California. Donor: R. A. Crippen, c/o New Idria Mining Company, Idria, California. August 9, 1944. In case 150.

21167 CLEAVELANDITE ($NaAlSi_3O_8$). A variety of albite feldspar from southwest side of Santa Rita Peak, southwest of New Idria, San Benito County, California. Donor: Maxwell Daugherty, c/o New Idria Mining Company, Idria, California. August 9, 1944. In case 125.

21168 MAGNETITE (Fe_3O_4). Crystals from altered serpentine near the Mexican quicksilver mine, western Fresno County, California. Donor: Maxwell Daugherty, c/o New Idria Mining Company, Idria, California. August 9, 1944. In case 224.

21169 DIADOCHITE. A hydrated phosphate and sulphate of ferric iron. A black, rubber-like material. Donor: J. M. Forbes, c/o New Idria Mining Company, Idria, California. August 9, 1944. In case 145.

21170 NATROLITE ($Na_2O.Al_2O_3.3SiO_2.2H_2O$). Crystals from Clear Creek, near Idria, San Benito County, California. Donor: J. M. Forbes, c/o New Idria Mining Company, Idria, California. August 9, 1944. In case 135.

21171 CINNABAR (HgS) showing polish by slickensides, from No. 5 level, No. 5 East Orebody, New Idria mine, San Benito County, California. Donor: J. M. Forbes, c/o New Idria Mining Company, Idria, California. August 9, 1944. In case 224.

21172 BORNITE, cooper ore from Magma Copper Company mine, Superior, Arizona. Donor: W. W. Simon, Superior, Arizona. August 1944. In case 315.

21173 CALCITE (fluorescent) from Sunset mine, Superior, Arizona. Donor: W. W. Simon, Superior, Arizona, August 1944. In case 806.

21174 PHOSPHORITE (phosphate rock) found in Monterey shales in Carmel Valley, Monterey County, California. Donor: O. P. Jenkins. September 6, 1944. In case 141.

---

* Statistician and Curator, Division of Mines.

LIBRARY

LIBRARY REPORT

By James M. Little *

OUTLINE OF REPORT

INTRODUCTION

The library of the Division of Mines contains more than 6,000 selected volumes on mines, mining, and allied subjects. It is also the repository for reports and bulletins of technical departments of Federal and State governments and educational institutions both domestic and foreign. Current copies of newspapers published in the mining centers of the State are also available for reference.

The library and reading room are open to the public during the usual office hours, when the librarian may be freely called upon for all necessary assistance.

PUBLICATIONS OF THE UNITED STATES GEOLOGICAL SURVEY AND UNITED STATES BUREAU OF MINES

The library of the Division of Mines has available for public reference the following publications of the United States Geological Survey: Annual Reports, Monographs, Professional Papers, Bulletins, Water-Supply Papers, Mineral Resources, Folios of the Geologic Atlas of the United States (broken file), Maps with Descriptive Text (broken file), Administrative Publications (broken file); and the following publications of the United States Bureau of Mines: Bulletins, Technical Papers, Economic Papers (broken file), Mineral Resources of the United States, Monographs (broken file), Reports of Investigations, Information Circulars.

Reports, mainly on California, recently received from the Survey and Bureau of Mines include:

U. S. Geological Survey

Bulletins

945-A Geology of the Grey Eagle and some nearby chromite deposits in Glenn County, California.

945-B Chromite deposits near San Luis Obispo, San Luis Obispo County, California.

* Librarian, Division of Mines.

U. S. Bureau of Mines

Reports of Investigations

3765 Ore testing studies on gold and gold-silver deposits.
3774 The composition and properties of molding sands.

Information Circulars

7295 Corundum, 1944.

PUBLICATIONS OF STATE SURVEYS

A broken file of mining and geological publications, issued by the organizations listed below, may be consulted in the library of the Division of Mines.

Alabama Geological Survey, University.
Alaska (Territorial Commissioner of Mines), Juneau.
Arizona Bureau of Mines, Tucson.
Arkansas Geological Survey, Little Rock.
Colorado Bureau of Mines, Denver.
Connecticut Geological and Natural History Survey, Hartford.
Florida Department of Conservation, Tallahassee.
Georgia Division of Geology, Atlanta.
Idaho Bureau of Mines and Geology, Moscow.
Illinois Geological Survey, Urbana.
Indiana Division of Geology, Indianapolis.
Iowa Geological Survey, Des Moines.
State Geological Survey of Kansas, Lawrence.
Kentucky Geological Survey, Frankfort.
Louisiana Department of Conservation, New Orleans.
Maine State Geologist, Augusta.
Maryland Geological Survey, Baltimore.
Michigan Geological Survey, Lansing.
Minnesota Geological Survey, Minneapolis.
Mississippi State Geological Survey, University.
Missouri Bureau of Geology and Mines, Rolla.
Montana Bureau of Mines and Geology, Butte.
Nebraska Geological Survey, Lincoln.
Nevada State Bureau of Mines, Reno.
New Jersey Department of Conservation and Development, Trenton.
New Mexico Bureau of Mines and Mineral Resources, Socorro.
New York Science Division, Albany.
North Carolina Geological and Economic Survey, Chapel Hill.
North Dakota Geological Survey, Grand Forks.
Ohio Geological Survey, Columbus.
Oklahoma Geological Survey, Norman.
Oregon State Department of Geology and Mineral Industries, Portland.
Pennsylvania Topographic and Geological Survey, Harrisburg.
South Dakota State Geological Survey, Vermillion.
Tennessee Division of Geology, Nashville.
Texas Bureau of Economic Geology, Austin.
Virginia Geological Survey, University.
Washington State Department of Conservation and Development, Pullman.
West Virginia Geological Survey, Morgantown.
Wisconsin Geological and Natural History Survey, Madison.
Wyoming Geological Survey, Cheyenne.

The following publications have been received recently from the California Division of Water Resources:

Bulletins

21-N Report on irrigation districts in California for the year 1942.
39-J South coastal basin investigation, ground-water levels, 1941, including San Joaquin and Antelope Valleys, precipitation records 1940-41.

PUBLICATIONS OF FOREIGN GOVERNMENTS

Publications of the following foreign governments are received and current issues may be consulted in the library. Earlier issues of foreign-language publications have been loaned to the California Asademy of Sciences in Golden Gate Park, because of the limited storage space at the Division's offices in the Ferry Building. They may, however, be consulted at the Academy.

Alberta Research Council, Edmonton.
Argentina Direccion General de Minas y Geologica, Buenos Aires.

British Columbia Minister of Mines, Victoria.
British Museum of Natural History, London.
Canada Department of Mines, Ottawa.
Cuerpo de Ingenieros de Minas y Aguas del Peru, Lima.
Geological Service of Minas Geraes, Bella Horizonte, Brazil.
Geological Survey of Scotland.
Instituto Historica e Geographico, Rio de Janeiro.
Museo de Historia Natural de Montevideo, Uruguay.
New South Wales Department of Mines, Sydney, Australia.
New Zealand Geological Survey Branch, Wellington.
Nova Scotia Department of Public Works and Mines, Halifax.
Ontario Department of Mines, Toronto, Canada.
Quebec Bureau of Mines, Quebec.
Queensland Department of Mines, Brisbane, Australia.
South Australia Department of Mines, Adelaide.
Transvaal Chamber of Mines, Johannesburg, South Africa.
Western Australia Geological Survey, Perth.

PUBLICATIONS OF FOREIGN AND DOMESTIC SOCIETIES AND EDUCATIONAL INSTITUTIONS

Academia de Ciencias y Artes de Barcelona, Spain.
Academy of Natural Sciences of Philadelphia.
American Association of Petroleum Geologists, Tulsa, Oklahoma.
American Geographical Society of New York.
American Institute of Mining and Metallurgical Engineers, New York.
American Journal of Science, New Haven, Conn.
American Philosophical Society, Philadelphia.
Australian Museum, Sydney.
California Academy of Sciences, San Francisco.
Canadian Institute of Mining and Metallurgy, Montreal.
Carnegie Institution of Washington.
Cleveland Museum of Natural History, Cleveland, Ohio.
Colorado College Publications, Colorado Springs.
Colorado Scientific Society, Denver.
Commonwealth Club, San Francisco.
Economic Geology, Lancaster, Pa.
Field Museum of Natural History, Chicago.
Franklin Institute of the State of Pennsylvania, Lancaster.
Geological Society of America, Columbia University, New York.
Geographical Society of London.
Institution of Mining and Metallurgy, London.
Instituto Geologico de Mexico, Mexico, D. F.
Journal of Geology, Chicago.
Mineralogical Society of America, Menasha, Wisconsin.
Michigan College of Mining and Technology, Houghton.
Mining and Metallurgical Society of America, New York.
Missouri School of Mines and Metallurgy, Rolla.
Museu Nacional, Rio de Janeiro.
National Research Council, Washington, D. C.
New York Academy of Sciences, New York.
New York State Museum, Albany.
Pennsylvania State College, State College.
Philippine Journal of Science, Manila.
Royal Society of South Australia, Adelaide.
Seismological Society of America, Stanford University.
Sierra Club, San Francisco.
Society of Economic Paleontologists and Mineralogists, Tulsa, Oklahoma.
Southern California Academy of Sciences, Los Angeles.
Stanford University, Palo Alto, California.
University of California Publications in Engineering, Geography, and Geology, Berkeley.
University of Harvard, Department of Mineralogy and Petrography, Cambridge, Mass.

The following *Special Papers* of the *Geological Society of America*, which pertain principally to the West Coast, have been acquired by the Library:

Special Paper

6 Grand Canyon of the Yellowstone, by A. D. Howard, 1937.

10 Eocene of western Oregon, by F. E. Turner, 1938.

16 Lower Cretaceous of California and Oregon, by F. M. Anderson, 1938.

31 Submarine topography off the California Coast, by Francis P. Shepard and K. O. Emery, 1941.

39 Eocene radiolarian faunas, by Bruce L. Clark and A. S. Campbell, 1942.

42 Bibliography of fossil vertebrates 1934-1938, by C. L. Camp, D. N. Taylor, and S. P. Welles, 1942.

43 Miocene fishes of southern California, by L. R. David, 1943.

47 Mesozoic and Cenozoic Arcidae, by P. W. Reinhart, 1943.

50 Bibliography of economic geology of South America, by J. T. Singewald, Jr., 1943.

51 Miocene radiolarian faunas from southern California, by A. S. Campbell and B. L. Clark, 1944.

CURRENT MAGAZINES

Current issues of the technical magazines listed below are on file in the reading room of the library, and may be consulted.

Asbestos, Philadelphia, Pennsylvania.
Brick and Clay Record, Chicago.
California Journal of Development, San Francisco.
California Mining Journal, Auburn.
California Oil World, Los Angeles.
California Safety News, San Francisco.
Canadian Mining Journal, Gardenvale, Quebec.
Chemical and Metallurgical Engineering, New York City.
Chemical Engineering and Mining Review, Melbourne, Australia.
Civil Engineering, New York City.
Colorado School of Mines, Golden, Colorado.
Engineering and Mining Journal, New York City.
Fuel Oil, Chicago, Illinois.
Fusion Facts, Whittier, California.
Gold, Toronto, Canada.
Grizzly Bear, Los Angeles.
Hercules Mixer, Wilmington, Delaware.
Independent Monthly, Tulsa, Oklahoma.
Lubrication, The Texas Co., New York City.
Metals and Alloys, Pittsburg, Pennsylvania.
Mining and Contracting Review, Salt Like City.
Mineralogist, Portland, Oregon.
Mining Congress Journal, Washington, D. C.
Mining and Industrial News, San Francisco.
Mining and Geological Journal, Melbourne, Victoria, Australia.
Mining Journal. London.
Mining Journal, Phoenix, Arizona.
Mining and Metallurgy, New York City.
Mining World, Seattle.
Nickel Steel Topics, New York City.
Northwest Mining News, Spokane, Washington.
Oil and Gas Journal, Tulsa, Oklahoma.
Oil, Paint and Drug Reporter, New York City.
Oil Weekly, Houston, Texas.
Pacific Purchaser, San Francisco.
Petroleum World, Los Angeles.
Queensland Government Mining Journal, Brisbane, Australia.
Rock Products, Chicago.
Rocks and Minerals, Peekskill, New York.
Scientific American, New York City.
Southwest Builder and Contractor, Los Angeles.
Standard Oil Bulletin, San Francisco.
Stone, New York City.
Western Mining News, San Francisco.

NEWSPAPERS

Current issues of the following papers are received and kept on file in the library:

Alaska Weekly, Seattle, Washington.
Amador Dispatch, Jackson, California.
Banner, Sonora, California.
Barstow Printer, Barstow, California.
Bridgeport Chronicle-Union, Bridgeport, California.
Calaveras Californian, Angels Camp, California.
Calaveras Prospect, San Andreas, California.
Daily Commercial News, San Francisco, California.
Del Norte Triplicate, Crescent City, California.
Denver Mining Record, Denver, Colorado.
Inyo Independent, Independence, California.
Inyo Register, Bishop, California.
Las Vegas Age, Las Vegas, Nevada.
Livermore Herald, Livermore, California.
Los Angeles Times, Los Angeles, California.
Mariposa Gazette, Mariposa, California.
Mining Press, Reno, Nevada.
Mohave Miner, Kingman, Arizona.

Morning Union, Grass Valley, California.
Mountain Messenger, Downieville, California.
Needles Nugget, Needles, California.
Oroville Mercury Register, Oroville, California.
Placer Herald, Auburn, California.
Placerville Times, Placerville, California.
Plumas Independent, Quincy, California.
Randsburg Times, Randsburg, California.
Tehachapi News, Tehachapi, California.
Terra Bella News, Terra Bella, California.
Tuolumne Independent, Sonora, California.
Tuloumne Prospector, Tuolumne, California.
Union Democrat, Sonora, California.
Weekly Trinity Journal, Weaverville, California.
Yreka Journal, Yreka, California.

NEW BOOKS

Recent accessions to the library are the following books:

Dana, J. D., and **Dana, E. S.,** The system of mineralogy, 7th ed., vol. 1, 834 pp., New York, John Wiley & Sons, Inc., 1944.

Petroleum World, Annual review for 1943, Los Angeles, Petroleum World, 1944.

Shimer, Hervey W., and **Shrock, Robert R.,** Index fossils of North America, 837 pp., New York, John Wiley & Sons, Inc., 1944.

SERVICES OF THE DIVISION OF MINES

The Division of Mines (formerly State Mining Bureau) is maintained for the purpose of assisting in all possible ways in the development of California's mineral resources.

As one means of offering tangible service to the mining public, the State Mineralogist for many years has issued an annual or a biennial report reviewing in detail the mines and mineral deposits of the various counties.

As a progressive step in advancing the interests of the mineral industry, and as permitting earlier distribution to the public, publication of the Annual Report of the State Mineralogist in the form of monthly chapters was begun in January 1922, and continued until March 1923. Owing to a lack of funds for printing this was changed to a quarterly publication, beginning in September 1923. For the same reason, beginning with the January 1924 issue, it became necessary to charge a subscription price. This covers approximately the cost of printing.

Pages are numbered consecutively throughout the year and an index to the complete report is included annually in the closing number.

Beginning with the 1930 issues, the activities and progress of the Geologic Branch are recorded also in these quarterly chapters. The important part that geology plays in the economic development of our mineral resources is further recognized in the change of title from *Mining in California* to California Journal of Mines and Geology, beginning with the January 1933 chapter.

While current activities of all descriptions are covered in these chapters, the practice of issuing from time to time technical reports on special subjects will be continued as well. A list of such reports now available is appended hereto, and the names of new bulletins will be added in the future as they are completed.

The chapters are subject to revision, correction and improvement. Constructive suggestions from the mining public will be gladly received, and are invited.

The one aim of the Division of Mines is to increase its usefulness and to stimulate the intelligent development of the wonderful, latent resources of the State of California.

TYPES OF REPORTS

In general the reports presented in these chapters are grouped into three classes:

1. Mines and mineral resources of a given county or area (describing kind, character, distribution and extent of development).

2. Specific economic and industrial mineral products (listing and describing the resources over the entire State of a given mineral substance, e.g., feldspar).

3. Geological reports on specific areas (recording results and conclusions with maps, derived from field studies; and tied in with economic possibilities and developments).

Reports of District Mining Engineers

In 1919-1920 the Mining Bureau was organized into four main geographical divisions, with the field work delegated to a mining engineer in each district, working out from field offices that were established in Redding, Auburn, San Francisco and Los Angeles, respectively. This move brought the office into closer personal contact with operators, and it has many advantages over former methods of conducting field work, including lower traveling-expense bills for the Bureau's engineers. In 1923 the Redding and Auburn field offices were consolidated and moved to Sacramento.

The Redding office was reestablished in 1928, and the boundaries of each district adjusted. The counties now included in each of the four divisions and the locations of the branch offices are shown on the frontispiece outline map of the State.

Reports of mining activities and development in each district, prepared by the District Engineer, will continue to appear under the proper field division heading.

Special Articles

Detailed technical reports on special subjects, the result of research work or extended field investigations, will continue to be issued as separate bulletins by the Division, as has been the custom in the past.

Shorter and less elaborate technical papers and articles by members of the staff and others are published in each number of California Journal of Mines and Geology.

These special articles cover a wide range of subjects both of historical and current interest; descriptions of new processes, or metallurgical and industrial plants, new mineral occurrences, and interesting geological formations, as well as articles intended to supply practical and timely information on the problems of the prospector and miner, such as the text of new laws and official regulations and notices affecting the mineral industry.

MAIL AND FILES

The Division of Mines maintains, in addition to its correspondence files and the library, a mine file which includes original reports on the various mines and mineral properties of all kinds in California.

During each quarterly period there are several thousand letters received and answered at the San Francisco office alone, covering almost every phase of prospecting, mining and developing mineral deposits, reduction problems, marketing of refined products and mining law. In addition to this, hundreds of oral questions are answered daily, both at the main office and the district offices, for the many inquirers who come in for personal interviews and to consult the files and library.

COMMERCIAL MINERAL NOTES

The producer and consumer of mineral products are mutually dependent upon each other for their prosperity, and one of the most direct aids rendered by this Division to the mining industry in the past has been that of bringing producers and consumers into direct touch with each other.

This work has been carried on largely by correspondence, supplemented by personal consultation. Lists of buyers of all the commercial

minerals produced in California have been made available to producers upon request, and likewise the owners of undeveloped deposits of various minerals, and producers of them, have been made known to those looking for raw mineral products.

When the publication of *Mining in California* was on a monthly basis, current inquiries from buyers and sellers were summarized and lists of mineral products or deposits 'wanted' or 'for sale' included in each issue.

It is important that inquiries of this nature reach the mining public as soon as possible and in order to avoid the delay incident to the present quarterly publication of CALIFORNIA JOURNAL OF MINES AND GEOLOGY, these lists are now issued monthly in the form of a mimeographed sheet under the title of *Commercial Mineral Notes*, and sent to those on the mailing list of CALIFORNIA JOURNAL OF MINES AND GEOLOGY.

EMPLOYMENT SERVICE

Following the establishment of the Mining Division branch offices in 1919, a free technical employment service was offered as a mutual aid to mine operators and technical men for the general benefit of the mineral industry.

Briefly summarized, men desiring positions are registered, the cards containing an outline of the applicant's qualifications, position wanted, salary desired, etc., and as notices of 'positions open' are received, the names and addresses of all applicants deemed qualified are sent to the prospective employer for direct negotiations.

Telephone and telegraphic communications are also given immediate attention.

Technical men, or those qualified for supervisory positions, and vacancies of like nature only, are registered, as no attempt will be made to supply mine and mill labor.

Registration cards for the use of both prospective employers and employees may be obtained upon request, and a cordial invitation is extended to the industry to make free use of the facilities afforded. Parties interested should communicate direct with our San Francisco office.

DETERMINATION OF MINERAL SAMPLES

Samples (limited to two at one time) of any mineral found in the State may be sent to the Division of Mines for identification, and the same will be classified free of charge. No samples will be determined if received from points outside the State. It must be understood that no assays, or quantitative determinations will be made. Samples should be in lump form if possible, and marked plainly with name of sender on outside of package, etc. No samples will be received unless delivery charges are prepaid. A letter should accompany sample, giving locality where mineral was found and the nature of the information desired.

PUBLICATIONS OF THE DIVISION OF MINES[*]

During the past sixty-three years, in carrying out the provisions of the organic act creating the former California State Mining Bureau, there have been published many reports, bulletins and maps which go to make up a library of detailed information on the mineral industry of the State, a large part of which could not be duplicated from any other source.

One feature that has added to the popularity of the publications is that many of them have been distributed without cost to the public, and even the more elaborate ones have been sold at a price which barely covers the cost of printing.

Owing to the fact that funds for advancing the work of this department have usually been limited, the reports and bulletins mentioned are printed in limited editions many of which are now entirely exhausted.

Copies of such publications are available for reference, however, in the offices of the Division of Mines, in the Ferry Building, San Francisco; State Building, Los Angeles; State Office Building, Sacramento; Redding; and Division of Oil and Gas at Santa Barbara, Santa Paula, Taft, Bakersfield, Coalinga. They may also be found in many public, private and technical libraries in California and other states and foreign countries.

A catalog of all publications from 1880 to 1917, giving a synopsis of their contents, is issued as Bulletin No. 77.

Publications in stock may be obtained postpaid by addressing the San Francisco, Los Angeles or Sacramento offices and enclosing the requisite amount.

Remittances of stamps in an amount not to exceed 26 cents, currency or coin will be accepted at sender's risk. Payment is preferred in the form of money orders.

Money orders should be made payable to the Division of Mines.

Write for latest revised price list.

---

[*] NOTE.—The Division of Mines frequently receives requests for some of the early Reports and Bulletins now out of print, and it will be appreciated if parties having such publications and wishing to dispose of them will advise this office.

REPORTS

Asterisks (**) indicate the publication is out of print.

Publication	Price (including postage and sales tax)
**First Annual Report of the State Mineralogist, 1880, 43 pp. Henry G. Hanks	----
**Second Annual Report of the State Mineralogist, 1882, 514 pp., 4 illustrations, 1 map. Henry G. Hanks	----
**Third Annual Report of the State Mineralogist, 1883, 111 pp., 21 illustrations. Henry G. Hanks	----
**Fourth Annual Report of the State Mineralogist, 1884, 410 pp., 7 illustrations. Henry G. Hanks	----
**Fifth Annual Report of the State Mineralogist, 1885, 234 pp., 15 illustrations. Henry G. Hanks	----
Sixth Annual Report of the State Mineralogist, Part I, 1886, 145 pp., 3 illustrations, 2 maps. Henry G. Hanks — Price $0.75, sales tax $0.02	$0.77
Part II, 1887, 222 pp., 36 illustrations. William Irelan, Jr. — Price $0.75, sales tax $0.02	.77
**Seventh Annual Report of the State Mineralogist, 1887, 315 pp. William Irelan, Jr.	----
**Eighth Annual Report of the State Mineralogist, 1888, 948 pp., 122 illustrations. William Irelan, Jr.	----
Ninth Annual Report of the State Mineralogist, 1889, 352 pp., 57 illustrations, 2 maps. William Irelan, Jr. — Price $1.15, sales tax $0.03	1.18
**Tenth Annual Report of the State Mineralogist, 1890, 983 pp., 179 illustrations, 10 maps. William Irelan, Jr.	----
Eleventh Report (First Biennial) of the State Mineralogist, for the two years ending September 15, 1892, 612 pp., 73 illustrations, 4 maps. William Irelan, Jr. — Price $1.50, sales tax $0.04	1.54
**Twelfth Report (Second Biennial) of the State Mineralogist, for the two years ending September 15, 1894, 541 pp., 101 illustrations, 5 maps. J. J. Crawford	----
**Thirteenth Report (Third Biennial) of the State Mineralogist, for the two years ending September 15, 1896, 726 pp., 93 illustrations, 1 map. J. J. Crawford	----
Chapters of the State Mineralogist's **Report, XIV** Biennial Period, 1913-1914, Fletcher Hamilton:	
**Mines and Mineral Resources, Amador, Calaveras and Tuolumne Counties, 172 pp., paper	----
Mines and Mineral Resources, **Colusa, Glenn, Lake, Marin, Napa, Solano, Sonoma and Yolo** Counties, 208 pp., paper — Price $0.50, sales tax $0.01	.51
Mines and Mineral Resources, **Del Norte, Humboldt and Mendocino** Counties, 59 pp., paper — Price $0.35, sales tax $0.01	.36
Mines and Mineral Resources, **Fresno, Kern, Kings, Madera, Mariposa, Merced, San Joaquin and Stanislaus** Counties, 220 pp., paper — Price $0.75, sales tax $0.02	.77
Mines and Mineral Resources of **Imperial and San Diego** Counties, 113 pp., paper — Price $0.50, sales tax $0.01	.51
**Mines and Mineral Resources, Shasta, Siskiyou and Trinity Counties, 180 pp., paper	----
**Fourteenth Report of the State Mineralogist, for the Biennial Period 1913-1914, Fletcher Hamilton, 1915:	
A General Report on the Mines and Mineral Resources of **Amador, Calaveras, Tuolumne, Colusa, Glenn, Lake, Marin, Napa, Solano, Sonoma, Yolo, Del Norte, Humboldt, Mendocino, Fresno, Kern, Kings, Madera, Mariposa, Merced, San Joaquin, Stanislaus, San Diego, Imperial, Shasta, Siskiyou and Trinity** Counties, 974 pp., 275 illustrations, cloth	----

REPORTS—Continued

Asterisks (**) indicate the publication is out of print.	Price (including postage and sales tax)
Chapters of the State Mineralogist's **Report, XV** Biennial Period, 1915-1916, Fletcher Hamilton:	
Mines and Mineral Resources, **Alpine, Inyo and Mono Counties, 176 pp., paper	----
Mines and Mineral Resources, **Butte, Lassen, Modoc, Sutter and Tehama** Counties, 91 pp., paper ---- Price $0.50, sales tax $0.01	$0.51
Mines and Mineral Resources, **El Dorado, Placer, Sacramento and Yuba Counties, 198 pp., paper	----
Mines and Mineral Resources, **Monterey, San Benito, San Luis Obispo, Santa Barbara and Ventura Counties, 183 pp., paper	----
Mines and Mineral Resources, **Los Angeles, Orange and Riverside Counties, 136 pp., paper	----
Mines and Mineral Resources, **San Bernardino and Tulare Counties, 186 pp., paper	----
****Fifteenth Report** of the State Mineralogist, for the Biennial Period 1915-1916, Fletcher Hamilton, 1917: A General Report on the Mines and Mineral Resources of **Alpine, Inyo, Mono, Butte, Lassen, Modoc, Sutter, Tehama, Placer, Sacramento, Yuba, Los Angeles, Orange, Riverside, San Benito, San Luis Obispo, Santa Barbara, Ventura, San Bernardino and Tulare** Counties, 990 pp., 413 illustrations, cloth	----
Chapters of the State Mineralogist's **Report XVI**, Biennial Period, 1917-1918, Fletcher Hamilton:	
Mines and Mineral Resources of **Nevada** County, 270 pp., paper ---- Price $1.00, sales tax $0.03	1.03
Mines and Mineral Resources of **Plumas** County, 188 pp., paper ---- Price $0.50, sales tax $0.01	.51
Mines and Mineral Resources of **Sierra** County, 144 pp., paper ---- Price $0.75, sales tax $0.02	.77
Seventeenth Report of the State Mineralogist, 1920, 'Mining in California during 1920,' Fletcher Hamilton; 562 pp., 71 illustrations, cloth ---- Price $2.50, sales tax $0.06	2.56
Eighteenth Report of the State Mineralogist, 1922, 'Mining in California,' Fletcher Hamilton. Chapters published monthly beginning with January, 1922:	
**January, **February, **March, April, May, June, July, August, September, October, November, December, 1922 ---- Price $0.30, sales tax $0.01	.31
Chapters of Nineteenth Report of the State Mineralogist, 'Mining in California,' Fletcher Hamilton and Lloyd L. Root. January, February, March, September, 1923 ---- Price $0.30, sales tax $0.01	.31
Chapters of Twentieth Report of the State Mineralogist, 'Mining in California,' Lloyd L. Root. Published quarterly. January, April, July, October, 1924, per copy ---- Price $0.30, sales tax $0.01	.31
Chapters of Twenty-first Report of the State Mineralogist, 'Mining in California,' Lloyd L. Root. Published quarterly:	
January, 1925, Mines and Mineral Resources of **Sacramento, Monterey and Orange** Counties ---- Price $0.30, sales tax $0.01	.31
April, 1925, Mines and Mineral Resources of **Calaveras, Merced, San Joaquin, Stanislaus and Ventura** Counties ---- Price $0.30, sales tax $0.01	.31
July, 1925, Mines and Mineral Resources of **Del Norte, Humboldt and San Diego Counties	----
October, 1925, Mines and Mineral Resources of **Siskiyou, San Luis Obispo and Santa Barbara Counties	----
Chapters of Twenty-second Report of the State Mineralogist, 'Mining in California,' Lloyd L. Root. Published quarterly:	
January, 1926, Mines and Mineral Resources of **Trinity and Santa Cruz Counties	----
April, 1926, Mines and Mineral Resources of **Shasta, San Benito and Imperial** Counties ---- Price $0.30, sales tax $0.01	.31

REPORTS—Continued

Asterisks (**) indicate the publication is out of print. — Price (including postage and sales tax)

July, 1926, Mines and Mineral Resources of **Marin and Sonoma** Counties Price $0.30, sales tax $0.01 — $0.31

October, 1926, Mines and Mineral Resources of **El Dorado and Inyo Counties, also report on **Minaret District**, Madera County — ----

Chapters of Twenty-third Report of the State Mineralogist, 'Mining in California,' Lloyd L. Root. Published quarterly:

January, 1927, Mines and Mineral Resources of **Contra Costa** County; Santa Catalina Island — Price $0.30, sales tax $0.01 — .31

April, 1927, Mines and Mineral Resources of **Amador and Solano** Counties Price $0.30, sales tax $0.01 — .31

July, 1927, Mines and Mineral Resources of **Placer and Los Angeles Counties — ----

October, 1927, Mines and Mineral Resources of **Mono** County Price $0.30, sales tax $0.01 — .31

Chapters of Twenty-fourth Report of the State Mineralogist, 'Mining in California,' Lloyd L. Root. Published quarterly:

January, 1928, Mines and Mineral Resources of **Tuolumne** County Price $0.30, sales tax $0.01 — .31

April, 1928, Mines and Mineral Resources of **Mariposa** County Price $0.30, sales tax $0.01 — .31

July, 1928, Mines and Mineral Resources of **Butte and Tehama Counties — ----

October, 1928, Mines and Mineral Resources of **Plumas and Madera** Counties — Price $0.30, sales tax $0.01 — .31

Chapters of Twenty-fifth Report of the State Mineralogist, 'Mining in California,' Walter W. Bradley. Published quarterly:

January, 1929, Mines and Mineral Resources of **Lassen, Modoc and Kern Counties; also on Special **Placer Machines** — ----

April, 1929, Mines and Mineral Resources of **Sierra, Napa, San Francisco and San Mateo Counties — ----

July, 1929, Mines and Mineral Resources of **Colusa, Fresno and Lake** Counties — Price $0.30, sales tax $0.01 — .31

October, 1929, Mines and Mineral Resources of **Glenn, Alameda, Mendocino and Riverside** Counties — Price $0.30, sales tax $0.01 — .31

Chapters of Twenty-sixth Report of the State Mineralogist, 'Mining in California,' Walter W. Bradley. Published quarterly:

January, 1930, Mines and Mineral Resources of **Santa Clara** County; also **Barite** in California — Price $0.40, sales tax $0.01 — .41

April, 1930, Mines and Mineral Resources of **Nevada County; also **Mineral Paint** Materials in California — ----

July, 1930, Mines and Mineral Resources of **Yuba and San Bernardino Counties; also Commercial **Grinding Plants** in California — ----

October, 1930, Mines and Mineral Resources of **Butte, Kings and Tulare** Counties; also **Geology of Southwestern Mono County** (Preliminary) Price $0.40, sales tax $0.01 — .41

Chapters of Twenty-seventh Report of the State Mineralogist, 'Mining in California,' Walter W. Bradley. Published quarterly:

January, 1931. Preliminary Report of Economic **Geology** of the **Shasta Quadrangle. Beryllium and Beryl.** The New **Tariff** and Nonmetallic Products. **Crystalline Talc. Decorative Effects in Concrete** Price $0.40, sales tax $0.01 — .41

April, 1931, Stratigraphy of the **Kreyenhagen Shale. Diatoms and Silicoflagellates** of the Kreyenhagen Shale. **Foraminifera** of the Kreyenhagen Shale. **Geology of Santa Cruz Island** Price $0.40, sales tax $0.01 — .41

July, 1931. (Yuba, San Bernardino Counties.**) **Feldspar, Silica, Andalusite and Cyanide** Deposits of California. Note on a Deposit of **Andalusite** in Mono County; its occurrence and chemical importance. Bill creating **Trinity and Klamath River Fish and Game District** and its effect upon mining — ----

REPORTS—Continued

Asterisks (**) indicate the publication is out of print. — Price (including postage and sales tax)

October, 1931. (**Alpine County.**) **Geology** of the **San Jacinto Quadrangle** south of San Gorgonio Pass, California. **Notes** on Mining Activities in **Inyo and Mono** Counties in July, 1931 — Price $0.40, sales tax $0.01 — $0.41

Chapters of Twenty-eighth Report of the State Mineralogist, 'Mining in California,' Walter W. Bradley. Published quarterly:

January, 1932, Economic Mineral Deposits of the **San Jacinto Quadrangle.** Geology and Physical Properties of **Building Stone** from Carmel Valley. Contributions to the Study of **Sediments.** Sediments of Monterey Bay. **Sanbornite** — Price $0.40, sales tax $0.01 — .41

April, 1932. Elementary **Placer Mining Methods and Gold Saving Devices. The **Pan, Rocker and Sluice Box. Prospecting for Vein Deposits. Bibliography** of Placer Mining — ----

**Abstract from April quarterly: Elementary Placer Mining Methods and Gold Saving Devices. Types of Deposits, Simple Equipment. Special Machines. Dry Washing. Black Sand Treatment. Marketing of Products. Placer Mining Areas. Laws. Prospecting for Quartz Veins. Bibliography (mimeographed)

July-October, (Ventura County). Report accompanying **Geologic Map of Northern Sierra Nevada. Fossil Plants in Auriferous Gravels of the Sierra Nevada. **Glacial and Associated Stream Deposits** of the Sierra Nevada. **Jurassic and Cretaceous Divisions** in the **Knoxville-Shasta Succession** of California. Geology of a part of the **Panamint Range.** Economic Report of a Part of the Panamint Range. Acquiring Mining Claims Through **Tax Title.** The Biennial Report of State Mineralogist — ----

Chapters of Report XXIX, 1933 (quarterly): title 'California Journal of Mines and Geology,' containing the following:

January-April. **Gold** Deposits of the **Redding and Weaverville Quadrangles. Geologic Formations** of the Redding-Weaverville District, Northern California. **Geology** of Portions of **Del Norte and Siskiyou** Counties. **Applications of Geology to Civil Engineering.** The **Lakes** of California. Discovery of **Piedmontite** in the Sierra Nevada. Tracing **'Buried River' Channel Deposits by Geomagnetic Methods.** Geologic Map of Redding-Weaverville District, showing gold mines and prospects. Geologic map showing various mines and prospects of part of Del Norte and Siskiyou Counties — Price $1.00, sales tax $0.03 — 1.03

July-October. **Gold** Resources of **Kern** County. **Limestone** Deposits of the **San Francisco** Region. **Limestone Weathering** and Plant Associations of the San Francisco Region. **Booming, Death Valley National Monument,** California. **Placer Mining Districts,** Senate Bill 480. **Navigable Waters,** Assembly Bill 1543 — Price $1.00, sales tax $0.03 — 1.03

Chapters of Report XXX, 1934 (quarterly): titled 'California Journal of Mines and Geology,' containing the following:

January. **Resurrection of Early Surfaces** in the Sierra Nevada. **Geology** and Mineral Resources of Northeastern **Madera** County. **Geology** and Mineral Deposits of **Laurel and Convict Basins,** Southwestern Mono County. Notes on **Sampling as Applied to Gold Quartz** Deposits — Price $0.60, sales tax $0.02 — .62

April-July. Elementary **Placer Mining** in California and Notes on the **Milling** of Gold Ores — Price $1.00, sales tax $0.03 — 1.03

October. Current Mining Developments in Northern California. Current Mining Activity in Southern California. Geology and Mineral Resources of the **Julian District,** San Diego County. Geology and Mineral Resources of **Elizabeth Lake Quadrangle. Dry Placers** of Northern **Mojave** Desert. Biennial Report of State Mineralogist. **Assessment Work** Within Withdrawn Areas — Price $0.60, sales tax $0.02 — .62

REPORTS—Continued

Asterisks (**) indicate the publication is out of print. | Price (including postage and sales tax)

Chapters of Report XXXI, 1935 (quarterly): titled 'California Journal of Mines and Geology,' containing the following:

January. Review of **Gold Mining** in **East-Central** California. 1934. Current Mining Activities in the **San Francisco District** with Special Reference to **Gold.** Geological Investigation of the **Clays of Riverside and Orange** Counties, Southern California. Information regarding **Mining Loans** by the Reconstruction Finance Corporation---------- Price $0.60, sales tax $0.02 $0.62

April. A Geologic Section Across the **Southern Peninsular Range** of California. **New Technique** Applicable to the **Study of Placers. Grubstake** Permits --------------------Price $0.60, sales tax $0.02 .62

July. Mines and Mineral Resources of **Siskiyou** County (with map). **Dams** for Hydraulic Mining **Debris. Leasing System** as Applied to Metal Mining. **Mine Financing** in California. New **Laws** Make Radical Change in Mining Rights--------Price $0.60, sales tax $0.02 .62

October. Mines and Mineral Resources of **San Luis Obispo** County. Mineral Resources of **Portions of Monterey and Kings** Counties. Mining Activity at **Soledad Mountain and Middle Buttes**—Mojave District, Kern County. Geology of a Portion of the **Perris Block,** Southern California. Mineral Resources of a Portion of the Perris Block, Riverside County-----------------Price $0.60, sales tax $0.02 .62

Chapters of Report XXXII, 1936 (quarterly): titled 'California Journal of Mines and Geology,' containing the following:

January. **Gold** Mines of **Placer County,** including **Drag-line Dredges.** Geologic Report on **Borax Lake,** California---------------------- Price $0.60, sales tax $0.02 .62

April. Geology, Mining and Processing of **Diatomite** at Lompoc, Santa Barbara County. Essentials in **Developing and Financing a Prospect** into a Mine. **Gold**-bearing Veins of **Meadow Lake District,** Nevada County. Semi-Precious **Gem Stone Collection** in Division Museum-- Price $0.60, sales tax $0.02 .62

July. Mines and Mineral Resources of **Calaveras** County. Mining in California by **Power Shovel. Assessment Work** on Mining Claims Within Withdrawn Areas. **Joshua Tree National Monument. Cost** of **Producing Quicksilver** at a California Mine in 1931-1932. The Age of **Mineral Utilization**--------------Price $0.60, sales tax $0.02 .62

October. Mineral Resources of **Lassen and Modoc** Counties. Mechanics of **Lone Mountain Landslides,** San Francisco. Biennial Report of the State Mineralogist, Properties and Industrial Applications of **Opaline Silica** -------------------------Price $0.60, sales tax $0.02 .62

Chapters of Report XXXIII, 1937 (quarterly): titled 'California Journal of Mines and Geology,' containing the following:

January. **Source Data** of the **Geologic Map** of California, January, 1937. The **Geology** of **Quicksilver** Ore Deposits. **Prospecting** for **Lode Gold** ---------------------------------Price $0.60, sales tax $0.02 .62

April. Mineral Resources of **Plumas** County (with Geologic Map). List of preferred **mineral names.** New **Placer Mining Debris Law** Price $0.60, sales tax $0.02 .62

July. Mineral Resources of **Los Angeles** County (with map showing principal Mines and Oil Fields.) Geology and mineral deposits of the Western **San Gabriel Mountains,** Los Angeles County--------- Price $0.60, sales tax $0.02 .62

October. Mineral Resources of the **Resting Springs** Region, Inyo County. Paleozoic Section in the **Nopah and Resting Springs** Mountains, Inyo County, California. Native **Arsenic** from Grass Valley, California-- Price $0.60, sales tax $0.02 .62

Chapters of Report XXXIV, 1938 (quarterly): titled 'California Journal of Mines and Geology,' containing the following:

REPORTS—Continued

Asterisks (**) indicate the publication is out of print. Price (including postage and sales tax)

**January. Mineral Development and mining Activity in Southern California during the year 1937. Doing Something About Earthquakes. Gold and Petroleum in California. Gem Minerals of California. Lapidary Art ---- ----

April. Gold dredging in Shasta, Siskiyou and Trinity Counties; Geology of the Central Santa Monica Mountains; Marketing Mica---- Price $0.60, sales tax $0.02 $0.62

July. El Dorado County, Mineral High-Lights of California; Strategic Minerals of California; Cyanide Treatment of Gossan at Mountain Copper Co.; Submarine Canyons off the California Coast---- Price $0.60, sales tax $0.02 .62

October, Inyo County, Biennial Report of State Mineralogist, Sulphur Deposits of Inyo County, Geology of the Darwin-Lead Mining District ----Price $0.60, sales tax $0.02 .62

Chapters of Report XXXV, 1939 (quarterly) titled "California Journal of Mines and Geology," containing the following:

January, San Diego County, Geology and Oil Possibilities of Southwestern San Diego Co.; Prospect for 'Minor Metals' and Nonmetallic Minerals; The Right to Mine----Price $0.60, sales tax $0.02 .62

April, Shasta County, Public's Interest in Mine Taxation---- Price $0.60, sales tax $0.02 .62

July, Tertiary Formations of Northern Sacramento Valley, California; Geology and Oil Possibilities of Caliente Range, Cuyama Valley and Carrizo Plain, California; Bibliography of the Geology and Mineral Resources of California for the year 1937; the Giant Goose Lake Meteorite from Modoc County, California--Price $0.60, sales tax $0.02 .62

**October, Quicksilver Resources of California; Sulphate Minerals of the Leviathan Sulphur Mine, Alpine County, California---- ----

Reprint of Quicksilver Resources----Price $0.50, sales tax $0.02 .52

Chapter of Report XXXVI, 1940 (quarterly) titled "California Journal of Mines and Geology," containing the following:

January Current Mining Activity in Southern California; Notes on Beryl with a Qualitative Analysis for Beryllium; Strategic Minerals Investigations Procedure followed by the U. S. Bureau of Mines---- Price $0.60, sales tax $0.02 .62

April, Mineral Resources of Mono County; General Geology and Ores of the Blind Spring Hill Mining District, Mono County, California; Short Report on the Geological Formations Encountered in Driving the Mono Craters Tunnel; Methods and Costs of Mining and Concentrating Chromite ----Price $0.60, sales tax $0.02 .62

July, Economic Mineral Deposits of the Newberry and Ord Mountains, San Bernardino County; Geology of the Newberry and Ord Mountains, San Bernardino County, California; Notes on the Geology of a Portion of the Calico Mountains, San Bernardino County, California; Study of Chrome Process Aided by Martin Dennis Company Price $0.60, sales tax $0.02 .62

October, Mineral Resources of the Kernville Quadrangle; Strategic Problems of the Mineral Industry in California; Descriptive Geology of the Kernville Quadrangle, California; Biennial Report of the State Mineralogist; Strategic Tax Exemption; Federal Loans for Strategic Minerals ----Price $0.60, sales tax $0.02 .62

Chapters of Report XXXVII, 1941 (quarterly) titled "California Journal of Mines and Geology," containing the following:

January, Mineral Resources of Trinity County; Strategic Minerals Procurement; Geologic Investigation of the Chromite Deposits of California; United States Supreme Court Renders Far-reaching Decision on Power Permits on "Navigable" Streams; Securities and Exchange Commission ----Price $0.60, sales tax $0.02 .62

REPORTS—Continued

Asterisks (**) indicate the publication is out of print.	Price (including postage and sales tax)
April. **Tungsten** Resources of California; **Geological Progress** of State Division of Mines; California **Earthquakes** of Mission Period, 1769-1838 ---------- Price $0.60, sales tax $0.02	$0.62
July, (**Nevada** County Report and Maps) Mines and Mineral Resources of Nevada County; **Price of Gold** ---------- Price $0.60, sales tax $0.02	.62
October, (**Humboldt** County) Mineral Resources of Humboldt County; Recent Developments in the **Tungsten** Resources of California; **Tin** in California ---------- Price $0.60, sales tax $0.02	.62
Chapters of Report XXXVIII, 1942 (quarterly) titled "California Journal of Mines and Geology," containing the following:	
January, Mines and Mineral Resources of **Sierra** County; **Chromium** ---------- Price $0.60, sales tax $0.02	.62
April, Mineral Resources of **Imperial** County (report and map); Geology and Mineral Deposits of the **Cargo Muchacho Mountains,** Imperial County (map and report); Imperial **Carbon Dioxide Gas** Field; Legendary **"White Metal"** and Its "Ore"; **Mine Assessment Work** Suspended on Claims Within Withdrawn Areas ---------- Price $0.60, sales tax $0.02	.62
July-October, **Tungsten.** Tabulated list of deposits; Economic Mineral Map No. 4—Tungsten; Geology of **Ghost Canyon Deposit,** Madera County; Geology of **Welsh Deposit,** Madera County; Geology of **Confidence Mining District** Deposits, Tuolumne County; **Contact-Metamorphic Rocks** of **Twin Lakes Region,** Fresno County; **Coso Hot Springs** Geology; Biennial Report of State Mineralogist ---------- Price $1.20, sales tax $0.03	1.23
Chapters of Report XXXIX, 1943 (quarterly) titled "California Journal of Mines and Geology," containing the following:	
January, Mines and Mineral Resources of **Santa Cruz** County (report and map); **Organization and Service of the Division of Mines;** Recent Activity in the **Strategic Minerals** in the San Francisco, Los Angeles, Sacramento, and Redding Field Districts; Department of **Interior Information Service** ---------- Price $0.60, sales tax $0.02	.62
April. **Manganese** Discovery in **San Mateo** County. Current Activities in Strategic Minerals. Clerbus-Mae **Tungsten** Prospect, **Trinity** County. **Mylonites** of Eastern **San Gabriel Mountains.** Geology and **Tungsten** of **Sierra Nevada** N. E. of Visalia, **Tulare** County. Geology of **San Benito Quadrangle,** with map. **Lithium. Quartz** ---------- Price $0.60, sales tax $0.02	.62
July. **Carbon Dioxide,** Mendocino and Southern Sonoma Counties. Current Activities in Strategic Minerals. **Crestmore** Minerals. **Isometrograph** as Developed and Used at New Idria Mine. Sutter (Marysville) **Gas Field. Sillimanite** Group of Minerals. New Federal and State **Legislation** ---------- Price $0.60, sales tax $0.02	.62
October. **San Bernardino County** report and map. Current Notes on Activity in Strategic Minerals. Biennial Report of State Mineralogist ---------- Price $0.60, sales tax $0.02	.62
Map of **San Bernardino Co.,** sold separately ---------- Price $0.15, sales tax $0.01	.16
Chapters of Report XL, 1944 (quarterly), titled "California Journal of Mines and Geology," containing the following:	
January. Geology of Palm Springs-Blythe, **Riverside** County. Geology of Parts of Barstow Quadrangle, **San Bernardino** County. Geology of Needles-Goffs Region, **San Bernardino** County. **Airox** Concrete Aggregate. **Marketing** Magnesite and Allied Products ---------- Price $0.60, sales tax $0.02	.62

Yearly **subscriptions,** $2.00, sales tax, $0.05, $2.05; payable in advance.

BULLETINS

Asterisks (**) indicate the publication is out of print.

	Price (including postage and sales tax)
Bulletin No. 1. Description of Some **Desiccated Human Remains, by Winslow Anderson. 1888, 41 pp., 6 illustrations	----
Bulletin No. 2. Methods of Mine **Timbering, by W. H. Storms. 1894, 58 pp., 75 illustrations	----
Bulletin No. 3. **Gas and Petroleum Yielding Formations of Central Valley of California, by W. L. Watts. 1894, 100 pp., 13 illustrations, 4 maps	----
Bulletin No. 4. Catalogue of California **Fossils, by J. G. Cooper. 1894, 73 pp., 67 illustrations. (Part I was published in the Seventh Annual Report of the State Mineralogist, 1887)	----
Bulletin No. 5. The **Cyanide Process, 1894, by Dr. A. Scheidel. 140 pp., 46 illustrations	----
Bulletin No. 6. California **Gold Mill Practices, 1895, by E. B. Preston, 85 pp., 46 illustrations	----
Bulletin No. 7. Mineral **Production of California, by Counties, for the year **1894,** by Charles G. Yale. Tabulated sheet	----
Bulletin No. 8. Mineral **Production of California, by Counties, for the year **1895,** by Charles G. Yale. Tabulated sheet	----
Bulletin No. 9. **Mine Drainage, Pumps, etc., by Hans C. Behr. 1896, 210 pp., 206 illustrations	----
Bulletin No. 10. A **Bibliography Relating to the Geology, Paleontology and Mineral Resources of California, by Anthony W. Vogdes. 1896, 121 pp.	----
Bulletin No. 11. **Oil and Gas Yielding Formations of Los Angeles, Ventura and Santa Barbara Counties, by W. L. Watts. 1897, 94 pp., 6 maps, 31 illustrations	----
Bulletin No. 12. Mineral **Production of California, by Counties, for **1896,** by Charles G. Yale. Tabulated sheet	----
Bulletin No. 13. Mineral **Production of California, by Counties, for **1897,** by Charles G. Yale. Tabulated sheet	----
Bulletin No. 14. Mineral **Production of California, by Counties, for **1898,** by Charles G. Yale	----
Bulletin No. 15. **Map of Oil City Fields, Fresno County, by John H. Means, 1899	----
Bulletin No. 16. The **Genesis of Petroleum and Asphaltum in California, by A. S. Cooper. 1899, 39 pp., 29 illustrations	----
Bulletin No. 17. Mineral **Production of California, by Counties, for **1899,** by Charles G. Yale. Tabulated sheet	----
Bulletin No. 18. **Mother Lode Region of California, by W. H. Storms, 1900, 154 pp., 49 illustrations	----
Bulletin No. 19. **Oil and Gas Yielding Formations of California, by W. L. Watts. 1900, 236 pp., 60 illustrations, 8 maps	----
Bulletin No. 20. **Synopsis of General Report of State Mining Bureau, by W. L. Watts. 1901, 21 pp. This bulletin contains a brief statement of the progress of the mineral industry in California for the four years ending December, 1899	----
Bulletin No. 21. Mineral **Production of California by Counties, by Charles G. Yale. **1900.** Tabulated sheet	----
Bulletin No. 22. Mineral **Production of California **for Fourteen Years,** by Charles G. Yale. 1900. Tabulated sheet	----
Bulletin No. 23. The **Copper** Resources of California, by P. C. DuBois, F. M. Anderson, J. H. Tibbits and G. A. Tweedy. 1902, 282 pp., 69 illustrations, 9 maps Price $0.75, sales tax $0.02	$0.77
Bulletin No. 24. The **Saline Deposits of California, by G. E. Bailey. 1902, 216 pp., 99 illustrations, 5 maps	----
Bulletin No. 25. Mineral **Production of California, by Counties, for **1901,** by Charles G. Yale. Tabulated sheet	----

BULLETINS—Continued

Asterisks (**) indicate the publication is out of print. — Price (including postage and sales tax)

**Bulletin No. 26. Mineral Production of California for the Past Fifteen Years, by Charles G. Yale. 1902. Tabulated sheet ---- ----

**Bulletin No. 27. The Quicksilver Resources of California, by William Forstner. 1903, 273 pp., 144 illustrations, 8 maps ---- ----

**Bulletin No. 28. Mineral Production of California for 1902, by Charles G. Yale. Tabulated sheet ---- ----

**Bulletin No. 29. Mineral Production of California for Sixteen Years, by Charles G. Yale. 1903. Tabulated sheet ---- ----

**Bulletin No. 30. Bibliography Relating to the Geology, Paleontology and Mineral Resources of California, by A. W. Vogdes. 1903, 290 pp. ----

**Bulletin No. 31. Chemical Analyses of California Petroleum, by H. N. Cooper. 1904. Tabulated sheet ---- ----

**Bulletin No. 32. Production and Use of Petroleum in California, by Paul W. Prutzman. 1904, 230 pp., 116 illustrations, 14 maps ---- ----

**Bulletin No. 33. Mineral Production of California, by Counties, for 1903, by Charles G. Yale. Tabulated sheet ---- ----

**Bulletin No. 34. Mineral Production of California for Seventeen Years, by Charles G. Yale. 1904. Tabulated sheet ---- ----

**Bulletin No. 35. Mines and Minerals of California, by Charles G. Yale. 1904, 55 pp., 20 county maps. Relief maps of California ---- ----

**Bulletin No. 36. Gold Dredging in California, by J. E. Doolittle. 1905. 120 pp., 60 illustrations, 3 maps ---- ----

**Bulletin No. 37. Gems, Jewelers' Materials, and Ornamental Stones of California, by George F. Kunz. 1905, 168 pp., 54 illustrations ---- ----

**Bulletin No. 38. Structural and Industrial Materials of California, by Wm. Forstner, T. C. Hopkins, C. Naramore and L. H. Eddy. 1906, 412 pp., 150 illustrations, 1 map ---- ----

**Bulletin No. 39. Mineral Production of California, by Counties, for 1904, by Charles G. Yale. Tabulated sheet ---- ----

**Bulletin No. 40. Mineral Production of California for Eighteen Years, by Charles G. Yale. 1905. Tabulated sheet ---- ----

**Bulletin No. 41. Mines and Minerals of California for 1904, by Charles G. Yale. 1905, 54 pp., 20 county maps ---- ----

**Bulletin No. 42. Mineral Production of California, by Counties, 1905, by Charles G. Yale. Tabulated sheet ---- ----

**Bulletin No. 43. Mineral Production of California for Nineteen Years, by Charles G. Yale. Tabulated sheet ---- ----

**Bulletin No. 44. California Mines and Minerals for 1905, by Charles G. Yale. 1907, 31 pp., 20 county maps ---- ----

**Bulletin No. 45. Auriferous Black Sands of California, by J. A. Edman, 1907. 10 pp. ---- ----

**Bulletin No. 46. General Index of Publications of the California State Mining Bureau, by Charles G. Yale. 1907, 54 pp. ---- ----

**Bulletin No. 47. Mineral Production of California, by Counties, 1906, by Charles G. Yale. Tabulated sheet ---- ----

**Bulletin No. 48. Mineral Production of California for Twenty Years, by Charles G. Yale. 1906 ---- ----

**Bulletin No. 49. Mines and Minerals of California for 1906, by Charles G. Yale. 34 pp. ---- ----

Bulletin No. 50. The Copper Resources of California, 1908, by A. Hausman, J. Kruttschnitt, Jr., W. E. Thorn and J. A. Edman, 366 pp., 74 illustrations. (Revised edition) ---- Price $1.50, sales tax $0.04 $1.54

**Bulletin No. 51. Mineral Production of California, by Counties, 1907, by D. H. Walker. Tabulated sheet ---- ----

**Bulletin No. 52. Mineral Production of California for Twenty-one Years, by D. H. Walker. 1907. Tabulated sheet ---- ----

**Bulletin No. 53. Mineral Production of California for 1907, with County Maps, by D. H. Walker, 62 pp. ---- ----

BULLETINS—Continued

Asterisks (**) indicate the publication is out of print.	Price (including postage and sales tax)
Bulletin No. 54. Mineral **Production of California, by Counties, by D. H. Walker. **1908.** Tabulated sheet	----
Bulletin No. 55. Mineral **Production of California **for Twenty-two Years,** by D. H. Walker. 1908. Tabulated sheet	----
Bulletin No. 56. Mineral **Production for **1908,** with County Maps and Mining Laws of California, by D. H. Walker, 78 pp.	----
Bulletin No. 57. **Gold Dredging in California, by W. B. Winston and Chas. Janin. 1910, 312 pp., 239 illustrations, 10 maps	----
Bulletin No. 58. Mineral **Production of California, by Counties, by D. H. Walker. **1909.** Tabulated sheet	----
Bulletin No. 59. Mineral **Production of California **for Twenty-three Years,** by D. H. Walker. 1900. Tabulated sheet	----
Bulletin No. 60. Mineral **Production for **1909,** with County Maps and Mining Laws of California, by D. H. Walker. 94 pp.	----
Bulletin No. 61. Mineral **Production of California, by Counties, for **1910,** by D. H. Walker. Tabulated sheet	----
Bulletin No. 62. Mineral **Production of California **for Twenty-four Years,** by D. H. Walker. 1910. Tabulated sheet	----
Bulletin No. 63. **Petroleum in Southern California, by P. W. Prutzman. 1912, 430 pp., 41 illustrations, 6 maps	----
Bulletin No. 64. Mineral **Production for **1911,** by E. S. Boalich. 49 pp.	----
Bulletin No. 65. Mineral **Production for **1912,** by E. S. Boalich. 64 pp.	----
Bulletin No. 66. **Mining Laws of the United States and California. 1914, 89 pp.	----
Bulletin No. 67. **Minerals of California, by Arthur S. Eakle. 1914, 226 pp.	----
Bulletin No. 68. Mineral **Production for **1913,** with County Maps and Mining Laws, by E. S. Boalich. 160 pp.	----
Bulletin No. 69. **Petroleum Industry of California, with Folio of Maps (18 by 22), by R. P. McLaughlin and C. A. Waring. 1914, 519 pp., 13 illustrations, 83 figs. [18 plates in accompanying folio.]	----
Bulletin No. 70. Mineral **Production for **1914,** with County Maps and Mining Laws. 184 pp.	----
Bulletin No. 71. Mineral **Production for **1915,** with County Maps and Mining Laws, by Walter W. Bradley, 193 pp., 4 illustrations	----
Bulletin No. 72. The **Geologic Formations of California, by James Perrin Smith. 1916, 47 pp.	----
****Reconnaissance Geologic Map** (of which Bulletin 72 is explanatory), in 23 colors. Scale: 1 inch = 12 miles. Mounted	----
Bulletin No. 73. **First Annual Report *of the* **State Oil and Gas Supervisor** of California for the fiscal year 1915-16, by R. P. McLaughlin. 278 pp., 26 illustrations	----
Bulletin No. 74. Mineral **Production of California in **1916,** with County Maps, by Walter W. Bradley. 179 pp., 12 illustrations	----
Bulletin No. 75. United States and California **Mining Laws. 1917, 115 pp., paper	----
Bulletin No. 76. **Manganese and Chromium** in California, by Walter W. Bradley, Emile Huguenin, C. A. Logan, W. B. Tucker and C. A. Waring. 1918, 248 pp., 51 illustrations, 5 maps, paper Price $0.75, sales tax $0.02	$0.77
Bulletin No. 77. **Catalogue of Publications** of California State Mining Bureau, 1880-1917, by E. S. Boalich. 44 pp., paper	Free
Bulletin No. 78. **Quicksilver Resources of California, with a Section on **Metallurgy and Ore-Dressing,** by Walter W. Bradley. 1919, 389 pp., 77 photographs and 42 plates (colored and line cuts), cloth	----
Bulletin No. 79. **Magnesite** in California, by Walter W. Bradley. 1925. 147 pp., 62 photographs, 11 line cuts and maps, cloth Price $1.25, sales tax $0.03	1.28

BULLETINS—Continued

Asterisks (**) indicate the publication is out of print. — Price (including postage and sales tax)

†Bulletin No. 80. **Tungsten. Molybdenum and Vanadium** in California. (Not issued—See Apr. 1941 Chapt. Report XXXVII.)

†Bulletin No. 81. **Foothill Copper Belt** of California. (Not issued.)

Bulletin No. 82. **Second Annual Report of the **State Oil and Gas Supervisor,** for the Fiscal Year 1916-1917, by R. P. McLaughlin. 1918, 412 pp., 31 illustrations, cloth ---- ----

Bulletin No. 83. California Mineral **Production for 1917, with County Maps, by Walter W. Bradley. 179 pp., paper ---- ----

Bulletin No. 84. **Third Annual Report of the **State Oil and Gas Supervisor,** for the Fiscal Year 1917-1918, by R. P. McLaughlin. 1918. 617 pp., 28 illustrations, cloth ---- ----

Bulletin No. 85. **Platinum and Allied Metals in California, by C. A. Logan, 1919. 10 photographs, 4 plates, 120 pp., paper ---- ----

Bulletin No. 86. California Mineral **Production for 1918, with County Maps, by Walter W. Bradley. 1919, 212 pp., paper ---- ----

Bulletin No. 87. **Commercial Minerals of California, with notes on their uses, distribution, properties, ores, field tests and preparation for market, by W. O. Castello. 1920, 124 pp., paper ---- ----

Bulletin No. 88. California Mineral **Production for 1919, with County Maps, by Walter W. Bradley. 1920, 204 pp., paper ---- ----

Bulletin No. 89. **Petroleum Resources of California, with Special Reference to **Unproved Areas,** by Lawrence Vander Leck. 1921, 12 figures, 6 photographs, 6 maps in pocket, 186 pp., cloth ---- ----

Bulletin No. 90. California Mineral **Production for 1920, with County Maps, by Walter W. Bradley. 1921, 218 pp., paper ---- ----

Bulletin No. 91. **Minerals of California, by Arthur S. Eakle. 1923, 328 pp., cloth ---- ----

Bulletin No. 92. **Gold Placers of California, by Charles S. Haley. 1923, 167 pp., 36 photographs and 7 plates (colored and line cuts, also geological map), cloth ---- ----

Bulletin No. 93. California Mineral **Production for 1922, by Walter W. Bradley. 1923, 188 pp., paper ---- ----

Bulletin No. 94. California Mineral **Production for 1923, by Walter W. Bradley. 1924, 162 pp., paper ---- ----

Bulletin No. 95. Geology and Ore Deposits of the **Randsburg Quadrangle, by Carlton D. Hulin. 1925, 152 pp., 49 photographs, 13 line cuts, 1 colored geologic map, cloth ---- ----

Bulletin No. 96. California Mineral **Production for 1924, by Walter W. Bradley. 1925, 173 pp., paper ---- ----

Bulletin No. 97. California Mineral **Production for 1925, by Walter W. Bradley. 1926, 172 pp., paper ---- ----

Bulletin No. 98. American Mining **Law,** by A. H. Ricketts. 1931, 811 pp., flexible leather ---- Price $2.50, sales tax $0.06 $2.56

Bulletin No. 99. **Clay** Resources and Ceramic Industry of California, by Waldemar Fenn Dietrich. 1928, 383 pp., 70 photographs, 12 line cuts including maps, cloth ---- Price $2.00, sales tax $0.05 2.05

Bulletin No. 100. California Mineral **Production for 1926, by Walter W. Bradley. 1927, 174 pp., paper ---- ----

Bulletin No. 101. California Mineral **Production for 1927, by Henry H. Symons. 1928, 311 pp., paper ---- ----

Bulletin No. 102. California Mineral **Production for 1928, by Henry H. Symons. 1929, 210 pp., paper ---- ----

Bulletin No. 103. California Mineral **Production for 1929,** by Henry H. Symons. 1930, 231 pp., paper ---- ----

Bulletin No. 104. **Bibliography** of the Geology and Mineral Resources of California, to the end of 1930, by Solon Shedd ----
Price $2.50, sales tax $0.06 2.56

Bulletin No. 105. Mineral Production in **California for 1930 and Directory of Producers, by Henry H. Symons. 1931

BULLETINS—Continued

Asterisks (**) indicate the publication is out of print.	Price (including postage and sales tax)
Bulletin No. 106. Superseded. (See Bulletin No. 127.)	
Bulletin No. 107. Mineral Production in California for 1931 and Directory of Producers, by Henry H. Symons. 1932	
Bulletin No. 108. Mother Lode Gold Belt of California, by Clarence A. Logan. 1934, 240 pp., with geologic and claim maps, cloth Price $2.25, sales tax $0.06	$2.31
Bulletin No. 109. California Mineral Production and Directory of Mineral Producers for 1932, by Henry H. Symons, 200 pp., paper	----
Bulletin No. 110. California Mineral Production and Directory of Mineral Producers for 1933, by Henry H. Symons, 214 pp., paper	----
Bulletin No. 111. California Mineral Production and Directory of Mineral Producers for 1934, by Henry H. Symons, 334 pp., paper	----
Bulletin No. 112. California Mineral Production and Directory of Mineral Producers for 1935, by Henry H. Symons, 205 pp., paper	----
Bulletin No. 113. Minerals of California, by Adolf Pabst, 1938 Price $1.75, sales tax $0.04	1.79
Bulletin No. 114. California Mineral Production and Directory of Mineral Producers for 1936, by Henry H. Symons, 119 pp., paper	----
Bulletin No. 115. Bibliography of Geology and Mineral Resources of California, 1931 to 1936, by Solon Shedd, Supplementing Bulletin No. 104 Price $1.25, sales tax $0.03	1.28
Bulletin No. 116. California Mineral Production and Directory of Mineral Producers for 1937, by Henry H. Symons. 1938	
Bulletin No. 117. California Mineral Production and Directory of Mineral Producers for 1938, by Henry H. Symons. 1939	
Bulletin No. 118. Geologic Formations and Economic Development of the Oil and Gas Fields of California. (Includes map showing Oil and Gas Fields.)	
PREPRINTS of 4 Parts (not sold separately). Price per set $4.00, sales tax $0.10	4.10
Part I. "Development of the Industry."	
Part II. Geology of California and the Occurrence of Oil and Gas.	
Part III. Descriptions of Individual Oil and Gas Fields.	
Part IV. General Index, Glossary and Bibliography. Complete in one volume, cloth bound Price $6.00, sales tax $0.15	6.15
**Bulletin No. 119. Mineral Production of California for 1939, and Directory of Producers, by Henry H. Symons. 1940	----
**Bulletin No. 120. Superseded. (See Bulletin No. 127.)	
Bulletin No. 121. Mineral Production of California for 1940, and Directory of Producers, by Henry H. Symons. 1941	Free
Bulletin No. 122. Mineral Production of California for 1941; Directory of Producers, and Tables of Total Recorded Production by Counties, by Henry H. Symons, 377 pp., paper	Free
Bulletin No. 123. American Mining Law, by A. H. Ricketts, 1943, 1008 pp., cloth Price $5.00, sales tax $0.13	5.13
Bulletin No. 124. Commercial Minerals of California, by George L. Gary. A loose-leaf mimeographed bulletin arranged so that it may be revised and supplemented. 1942 Price $1.00, sales tax $0.03	1.03
With binder Price $1.30, sales tax $0.04	1.34
Revised papers mailed upon receipt of postage	
Bulletin No. 125. Manganese in California Price $3.00, sales tax $0.08	3.08
Bulletin No. 126. Mineral Production of California for 1942, and Directory of Producers, by Henry H. Symons, 1943 Price $0.75, sales tax $0.02	.77
Bulletin No. 127. Manner of Locating and Holding Mineral Claims in California (with forms), by A. H. Ricketts (revised 1944) Price $0.25, sales tax $0.01	.26

† Not issued.

PRELIMINARY REPORTS

Asterisks (**) indicate the publication is out of print.	Price (including postage and sales tax)
Preliminary Report No. 1. Notes on **Damage by Water in California Oil Fields, December, 1913. By R. P. McLaughlin, 4 pp.	----
Preliminary Report No. 2. Notes on **Damage by Water in California Oil Fields, March, 1914. By R. P. McLaughlin, 4 pp.	----
Preliminary Report No. 3. **Manganese and Chromium, 1917.** By E. S. Boalich. 32 pp.	Free
Preliminary Report No. 4. **Tungsten, Molybdenum and Vanadium. By E. S. Boalich and W. O. Castello, 1918. 34 pp. Paper	----
Preliminary Report No. 5. **Antimony, Graphite, Nickel, Potash, Strontium and Tin. By E. S. Boalich and W. O. Castello, 1918. 44 pp. Paper	----
Preliminary Report No. 6. A **Review of Mining** in California During **1919.** By Fletcher Hamilton, 1920. 43 pp. Paper	Free
Preliminary Report No. 7. The **Clay Industry in California. By E. S. Boalich, W. O. Castello, E. Huguenin, C. A. Logan, and W. B. Tucker, 1920. 102 pp. 24 illustrations. Paper	----
Preliminary Report No. 8. A **Review of Mining in California During **1921,** with Notes on the Outlook for 1922. By Fletcher Hamilton, 1922. 68 pp. Paper	----

MINERAL ABSTRACTS

Antimony, 26 pp.	Price $0.25, sales tax $0.01	$0.26
Iron, 52 pp.	Price $0.35, sales tax $0.01	.36
Pumice and Volcanic Ash, 50 pp.	Price $0.35, sales tax $0.01	.36
Sulphur, 23 pp.	Price $0.25, sales tax $0.01	.26
Tungsten, 33 pp.	Price $0.25, sales tax $0.01	.26

MISCELLANEOUS PUBLICATIONS

First Annual **Catalogue of the State **Museum** of California, being the collection made by the State Mining Bureau during the year ending April 16, 1881. 350 pp.	----
****Catalogue** of books, maps, lithographs, photographs, etc., in the **library** of the State Mining Bureau at San Francisco, May 15, 1884. 19 pp.	----
****Catalogue** of the State **Museum** of California, Volume II, being the collection made by the State Mining Bureau from April 16, 1881, to May 5, 1884. 220 pp.	----
****Catalogue** of the State **Museum** of California, Volume III, being the collection made by the State Mining Bureau from May 15, 1884, to March 31, 1887. 195 pp.	----
****Catalogue** of the State **Museum** of California, Volume IV, being the collection made by the State Mining Bureau from March 30, 1887, to August 20, 1890. 261 pp.	----
Lakes of California — Price $0.25, sales tax $0.01	.26
Drift Mining in California (Reprint) — Price $0.25, sales tax $0.01	.26
****Catalogue** of the **Library** of the California State Mining Bureau, September 1, 1892. 149 pp.	----
****Catalogue** of West North American and Many Foreign **Shells** with Their **Geographical Ranges** by J. G. Cooper. Printed for the State Mining Bureau, April, 1894	----
****Report** of the **Board of Trustees** for the four years ending September, 1900. 15 pp. Paper	----
Reconnaissance of the **Colorado Desert** Mining District. By Stephen Bowers, 1901. 19 pp. 2 illustrations. Paper	Free
Commercial Mineral Notes. A monthly mimeographed sheet, beginning April, 1923 (by mail 25c annually)	Free

Write for latest revised price list.

MAPS

Register of Mines with Maps

Asterisks (**) indicate the publication is out of print.

	Price (including postage and sales tax)
**Register of Mines, with Map, Amador County	----
Register of Mines, with Map, Butte County --Price $0.15, sales tax $0.01	$0.16
**Register of Mines, with Map, Calaveras County	----
**Register of Mines, with Map, El Dorado County	----
**Register of Mines, with Map, Inyo County	----
**Register of Mines, with Map, Kern County	----
**Register of Mines, with Map, Lake County	----
**Register of Mines, with Map, Mariposa County	----
Register of Mines, with Map, Nevada County	Free
**Register of Mines, with Map, Placer County	----
**Register of Mines, with Map, Plumas County	----
**Register of Mines, with Map, San Bernardino County	----
Register of Mines, with Map, San Diego County	Free
Register of Mines, with Map, Santa Barbara County (1906) Price $0.15, sales tax $0.01	.16
**Register of Mines, with Map, Shasta County	----
**Register of Mines, with Map, Sierra County	----
**Register of Mines, with Map, Siskiyou County	----
**Register of Mines, with Map, Trinity County	----
**Register of Mines, with Map, Tuolumne County	----
Register of Mines, with Map, Yuba County (1905) ---- Price $0.15, sales tax $0.01	.16
**Register of Oil Wells, with Map, Los Angeles City (1906)	----

Other Maps

**Map of California, Showing Mineral Deposits (50x60 in.)	----
**Map of Forest Reserves in California	----
**Mineral and Relief Map of California	----
**Map of El Dorado County, Showing Boundaries, National Forests	----
**Map of Madera County, Showing Boundaries, National Forests	-----
**Map of Placer County, Showing Boundaries, National Forests	----
**Map of Shasta County, Showing Boundaries, National Forests	----
**Map of Sierra County, Showing Boundaries, National Forests	----
**Map of Siskiyou County, Showing Boundaries, National Forests	----
**Map of Tuolumne County, Showing Boundaries, National Forests	----
**Map of Mother Lode Region	----
**Map of Desert Region of Southern California	----
Map of Minaret District, Madera County	.10
Map of Copper Deposits in California	Free
**Map of Calaveras County	----
**Map of Plumas County	----
**Map of Trinity County	----
**Map of Tuolumne County	----
**Geographical Map of Inyo County. Scale 1 inch equals 4 miles	----
**Map of California accompanying Bulletin No. 89, showing generalized classification of land with regard to oil possibilities. Map only, without Bulletin	----
**Geologic Map of California, 1916. Scale 1 inch equals 12 miles. Shows railroads, highways, post offices and other towns. Geological details lithographed in 23 colors. Mounted	----
**Unmounted	----
Geologic Map of California, 1938. Scale 8 miles per inch. Lithographed in 80 distinguishing colors and patterns showing geologic units. In 6 sections, each 32 in. x 42 in. Set of 6 sheets, unmounted. Sheets not sold separately ---- Price $4.00, sales tax $0.10	4.10

MAPS—Continued

Asterisks (**) indicate the publication is out of print.

	Price (including postage and sales tax)
Economic Series:	
No. 1. Quicksilver	
No. 2. Oil and Gas	
No. 3. Chromite	
No. 4. Tungsten	
No. 5. Manganese	
(See under separate listings below for prices)	
**Topographic Map of Sierra Nevada Gold Belt, showing distribution of auriferous gravels, accompanying Bulletin No. 92. In 4 colors	----
Map of Ancient Channel System, Calaveras County / Map of Ancient Channels Between San Andreas and Mokelumne Hill — Set of 2 ---- Price $0.25, sales tax $0.01	$0.26
Minaret	.10
Geologic Map of Northern Sierra Nevada, showing Tertiary River Channels and Mother Lode Belt accompanying July-October Chapter of Report XXVIII of the State Mineralogist. (Sold singly) ---- Price $0.25, sales tax $0.01	.26
Map of Northern California, showing rivers and creeks which produced placer gold in 1932 ---- Price $0.15, sales tax $0.01	.16
Mother Lode Geologic and claim maps in 5 county sections: El Dorado, Amador, Calaveras, Tuolumne and Mariposa, 5 maps, each ---- Price $0.15, sales tax $0.01	.16
Map of Mariposa County, showing principal gold mines ---- Price $0.15, sales tax $0.01	.16
Geologic Map of Elizabeth Lake Quadrangle, Los Angeles and Kern Counties (accompanying October Chapter of Report XXX), sold separately ---- Price	.10
Map of Western Portion of Siskiyou County Showing Location of Principal Gold Mines (accompanying July Chapter of Report XXXI), sold separately ---- Price $0.15, sales tax $0.01	.16
Geologic Map of Redding and Weaverville Quadrangles Showing Location of Gold Mines ---- Price $0.15, sales tax $0.01	.16
Perris Block Geologic	.10
Plumas County Geologic ---- Price $0.15, sales tax $0.01	.16
Shasta County Claims ---- Price $0.15, sales tax $0.01	.16
El Dorado County Claims ---- Price $0.15, sales tax $0.01	.16
Trinity County, Showing Locations of Principal Mineral Deposits (accompanying Jan. Chapt. of Report XXXVII) ---- Price $0.15, sales tax $0.01	.16
Quicksilver deposits, sold in conjunction with October 1939, Chapter of Report XXXV, Map separately ---- Price $0.50, sales tax $0.01	.51
Nevada County Claims (accompanying July chapter of Report XXXVII) Price $0.15, sales tax $0.01	.16
Grass Valley and Nevada City District claim map ---- Price	.10
Oil and Gas Fields Map, accompanying Bulletin 118, Map separately ---- Price $1.00, sales tax $0.03	1.03
Chromite deposits ---- Price $0.60, sales tax $0.02	.62
Inyo County Map, accompanying report on Mines and Minerals of Inyo County in October, 1938, Chapter of Report XXXIV, sold separately Price $0.15, sales tax $0.01	.16
San Diego County Map, accompanying Report on Mines and Mineral Resources of San Diego County in January, 1939, Chapter of Report XXXV, sold separately ---- Price $0.15, sales tax $0.01	.16
Mono County Map, accompanying report on mines and mineral resources of Mono County in April, 1940, Chapter of Report XXXVI, sold separately ---- Price	.10
Imperial County Map, accompanying report on mines and mineral resources of Imperial County in April, 1942, Chapter of Report XXXVIII, sold separately ---- Price	.10
Index map of Economic Minerals and Geomorphic Provinces	Free

MAPS—Continued

Asterisks (**) indicate the publication is out of print. Price (including postage and sales tax)

Tungsten deposits, sold in conjunction with July-October, 1942, Chapter of Report XXXVIII, Map separately-----Price $0.60, sales tax $0.02 $0.62

Santa Cruz County Map, accompanying report on mines and mineral resources of Santa Cruz County in January, 1943, Chapter of Report XXXIX, sold separately-----Price $0.15, sales tax $0.01 .16

San Benito Quadrangle Geologic Map, accompanying report on geology of area in April, 1943, Chapter of Report XXXIX, sold separately----Price $0.40, sales tax $0.01 .41

San Bernardino County Map, accompanying report on mines and mineral resources of San Bernardino County in October, 1943, Chapter of Report XXXIX, sold separately-----Price $0.15, sales tax $0.01 .16

Manganese Deposits, accompanying Bulletin 125, Map separately-----Price $0.60, sales tax $0.02 .62

OIL AND GAS FIELD MAPS

The following maps are on sale at the State Division of Oil and Gas, Ferry Building, San Francisco, and the various branch offices. The maps are revised as development work advances and ownerships change. Price includes postage and sales tax.

No.		*Price*
1	Sargent, Santa Clara County	$0.75
2	Santa Maria, including Cat Canyon — Los Alamos, Santa Barbara County	1.25
3	Santa Maria, including Casmalia and Lompoc, Santa Barbara County	1.25
4	Brea Olinda and East Coyote, Los Angeles, Orange Counties	1.25
6	Salt Lake—Beverly Hills, Los Angeles County	1.25
7	Sunset, including San Emidio, Kern County	1.25
8	South Midway, including Buena Vista Hills, Kern County	1.25
9	North Midway and McKittrick, Kern and San Luis Obispo Counties	1.25
10	South Belridge and McKittrick-Temblor oil fields, Kern County	1.25
11	Lost Hills and North Belridge, including Antelope Hills, Kern County	1.25
12	Devils Den, Kern County	1.00
13	Kern River and Kern Front fields, including portion of Poso Creek field, Kern County	1.00
14	Coalinga and East Coalinga Extension, Fresno County	1.50
15	Elk Hills, Kern County	1.25
16	Ventura-Ojai, Ventura County	1.25
17	Santa Paula-Ojai, including South Mountain, Ventura County	1.25
18	Sespe-Piru-Simi, including Bardsdale, Ventura County	1.50
18a	Newhall, Aliso Canyon, Newhall-Potrero, Del Valle and Oak Canyon, Los Angeles County	1.25
19	Arroyo Grande, San Luis Obispo County	1.00
20	Long Beach, Los Angeles County	1.75
21B	District 5, boundaries of areas including oil fields, Fresno, Kings and Kern Counties	1.00
21C	District 4, boundaries of areas including oil fields, Kern, Kings and Tulare Counties	1.25
22	District 3, boundaries of areas including oil fields, Santa Barbara County	.75
23	District 2, boundaries of areas including oil fields, Ventura County	1.00
24	District 1, boundaries of areas including oil fields, Los Angeles and Orange Counties	1.00
26	Huntington Beach, Orange County	1.50
27	Santa Fe Springs, Los Angeles County	1.25
28	Torrance, Los Angeles County	1.25
28a	Townlot area, Torrance field, Los Angeles County	.75
29	Dominguez, Los Angeles County	1.00
30	Rosecrans, Los Angeles County	1.25

No.	Price
31—Inglewood, Los Angeles County	$1.25
32—Seal Beach, Los Angeles and Orange Counties	1.25
33—Rincon, Ventura County	1.50
34—Mt. Poso and Poso Creek, Kern County	1.00
35—Round Mountain, Kern County	1.00
36—Kettleman North Dome and Middle Dome, Fresno and Kings Counties	1.50
37—Montebello, Los Angeles County	1.00
38—Whittier, Los Angeles County	1.25
39—West Coyote Oil Field, Los Angeles and Orange Counties	1.25
40—Elwood, Goleta (abandoned), La Goleta (gas), Santa Barbara County	1.25
41—Potrero, Los Angeles County	1.00
42—Playa del Rey, Los Angeles County	1.50
43—Capitan, Santa Barbara County	1.00
44—Mesa, Santa Barbara County	1.50
46—Richfield, Orange County	1.25
48—Mountain View and Edison, Kern County	1.25
49—Fruitvale, Kern County	1.00
50—Wilmington, Los Angeles County	1.25
51—Santa Maria Valley, Santa Barbara County	1.00
52—El Segundo and Lawndale, Los Angeles County	1.50
53—Rio Bravo and Greeley, Kern County	1.00
54—Wasco oil field, Buttonwillow and Semitropic (gas), Kern County	1.25
55—Canal, Canfield Ranch, Coles Levee, Strand, Ten Section, Kern County	1.25
56—Paloma, Kern County	1.25
57—Rio Vista (gas), Sacramento, Solano, and Contra Costa Counties	1.00
58—Trico Gas, Kern, Kings and Tulare Counties	1.00
59—Raisin City, Helm and Riverdale, including Wheatville area, Fresno County	1.25

INDEX TO VOLUME XL

Chapter 1, January *California Journal of Mines and Geology*, includes pp. 1-162.
Chapter 2, April *California Journal of Mines and Geology*, includes pp. 163-282.
Chapter 3, July *California Journal of Mines and Geology*, includes pp. 283-392.
Chapter 4, October *California Journal of Mines and Geology*, includes pp. 393-509.

A

B

C

D

E

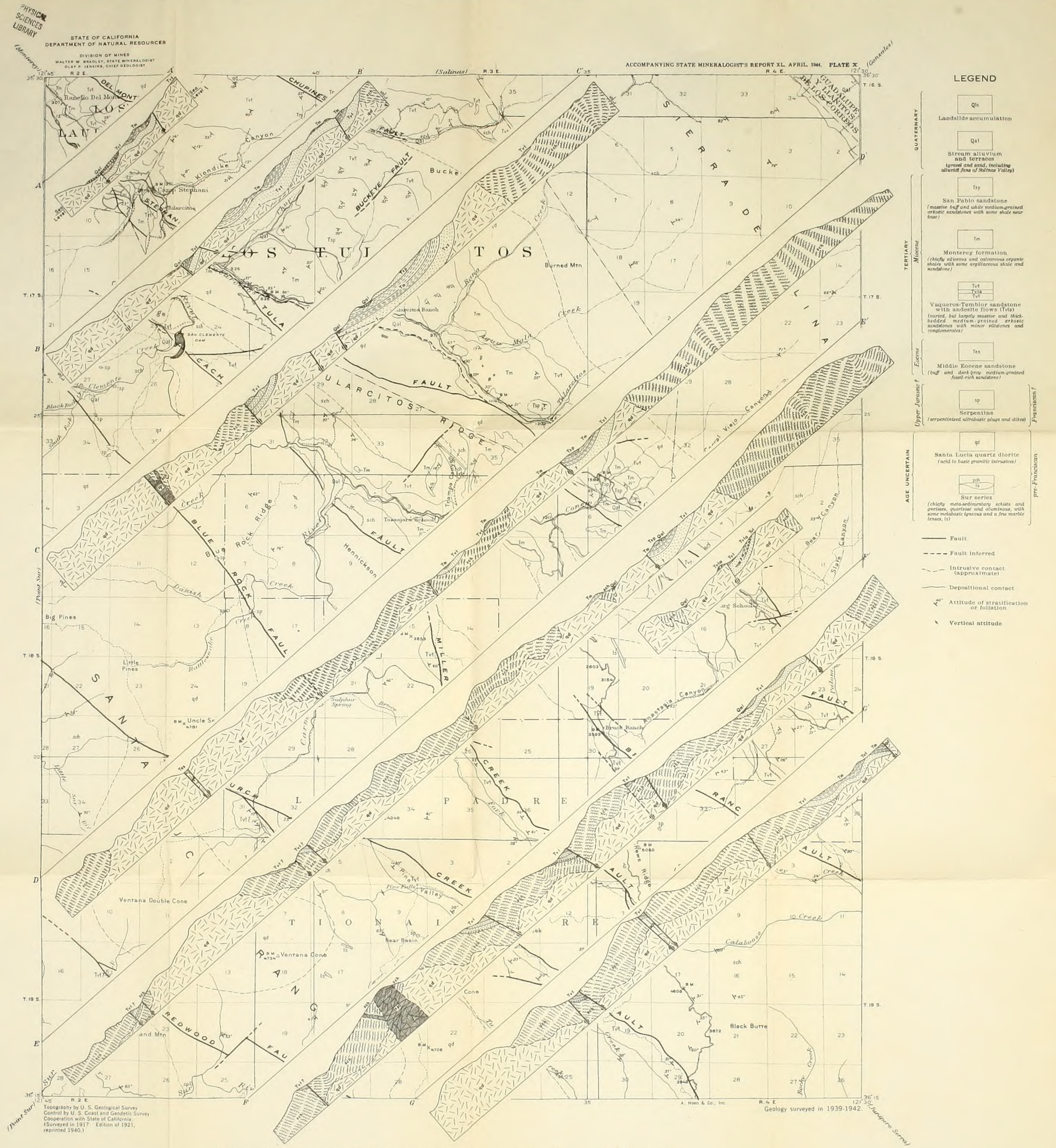
F

G

H

O

40276 6-45 2M



STRUCTURE SECTIONS ACROSS JAMESBURG QUADRANGLE MONTEREY COUNTY, CALIFORNIA

By William M. Fiedler

Scale 62500

Miles

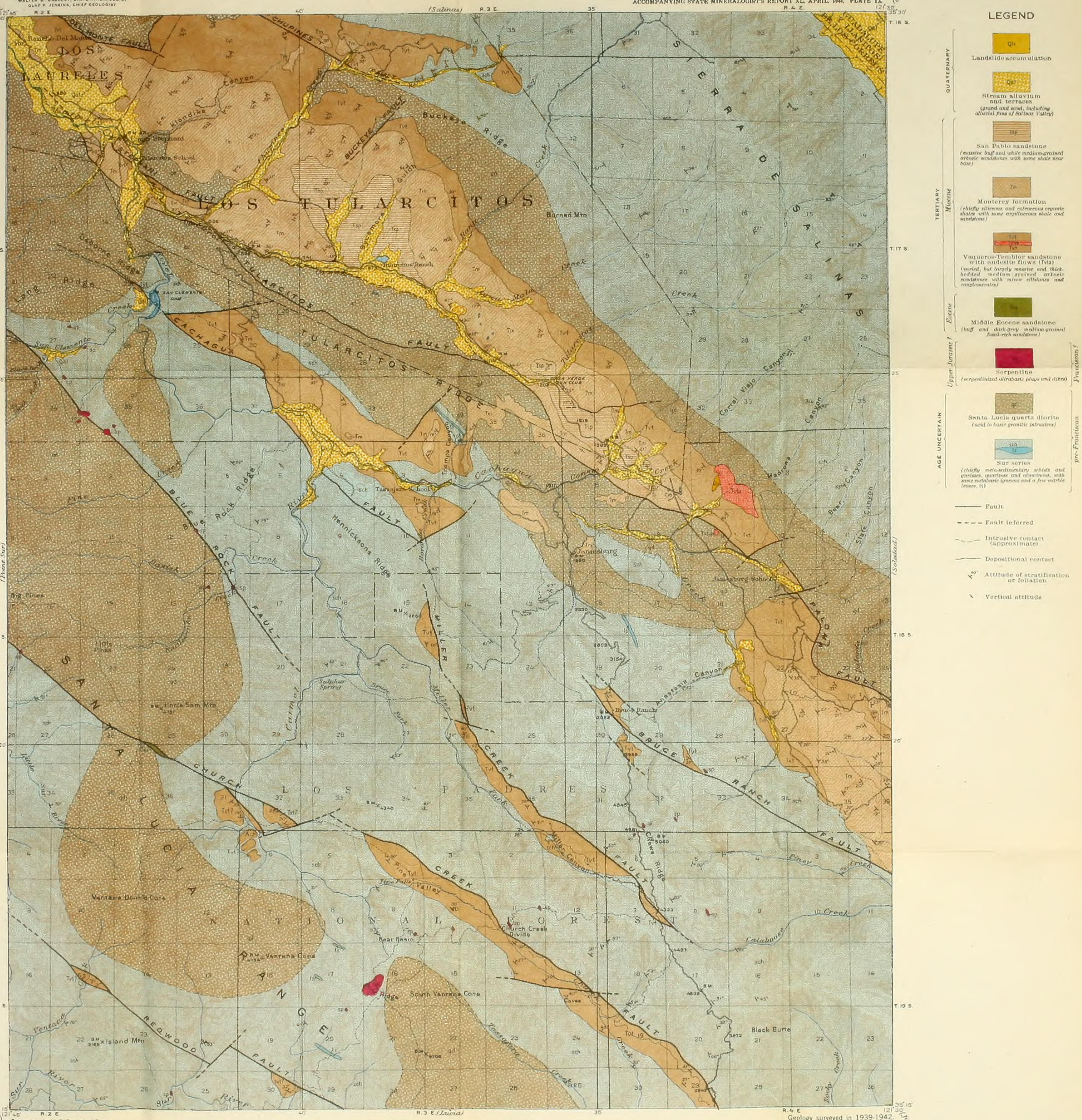
Kilometers

Contour interval 50 feet.
Datum is mean sea level.

APPROXIMATE MEAN DECLINATION, 1917

STATE OF CALIFORNIA
DEPARTMENT OF NATURAL RESOURCES
DIVISION OF MINES
WALTER W. BRADLEY, STATE MINERALOGIST
OLAF P. JENKINS, CHIEF GEOLOGIST

ACCOMPANYING STATE MINERALOGIST'S REPORT XL, APRIL, 1944, PLATE IX



Topography by U. S. Geological Survey
Control by U. S. Coast and Geodetic Survey
Cooperation with State of California.
(Surveyed in 1917. Edition of 1921, reprinted 1940.)

Geology surveyed in 1939-1942.

GEOLOGIC MAP OF THE JAMESBURG QUADRANGLE
MONTEREY COUNTY, CALIFORNIA

By William M. Fiedler

Scale $\frac{1}{62500}$

Miles

Kilometers

Contour interval 50 feet.

Datum is mean sea level.

DIVISION OF MINES
WALTER W. BRADLEY, STATE MINERALOGIST
OLAF P. JENKINS, CHIEF GEOLOGIST

STATE OF CALIFORNIA
DEPARTMENT OF NATURAL RESOURCES

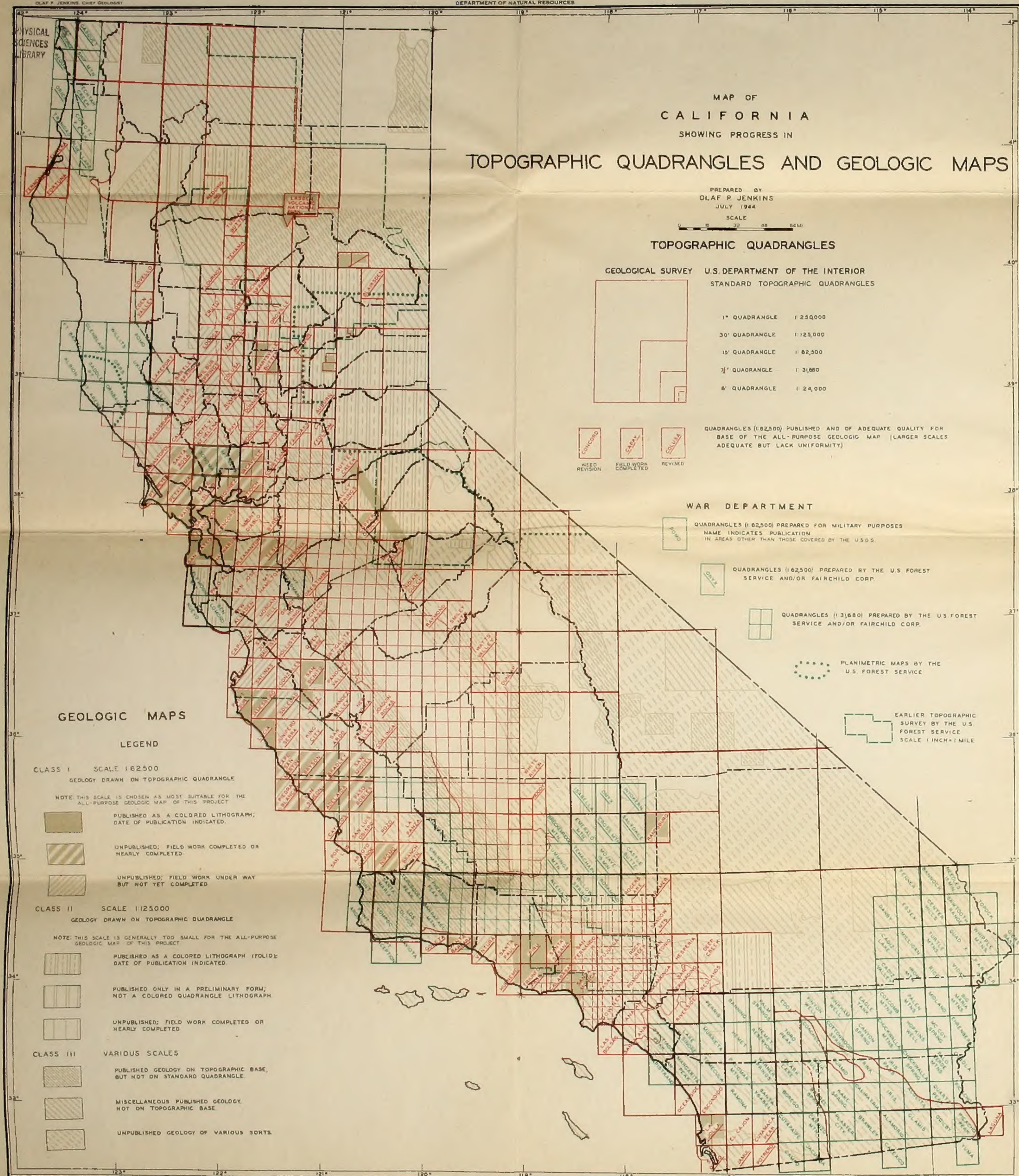


PLATE VIII. ACCOMPANYING STATE MINERALOGIST'S REPORT XL, APRIL, 1944

DIVISION OF MINES
WALTER W. BRADLEY, STATE MINERALOGIST
OLAF P. JENKINS, CHIEF GEOLOGIST

STATE OF CALIFORNIA
DEPARTMENT OF NATURAL RESOURCES

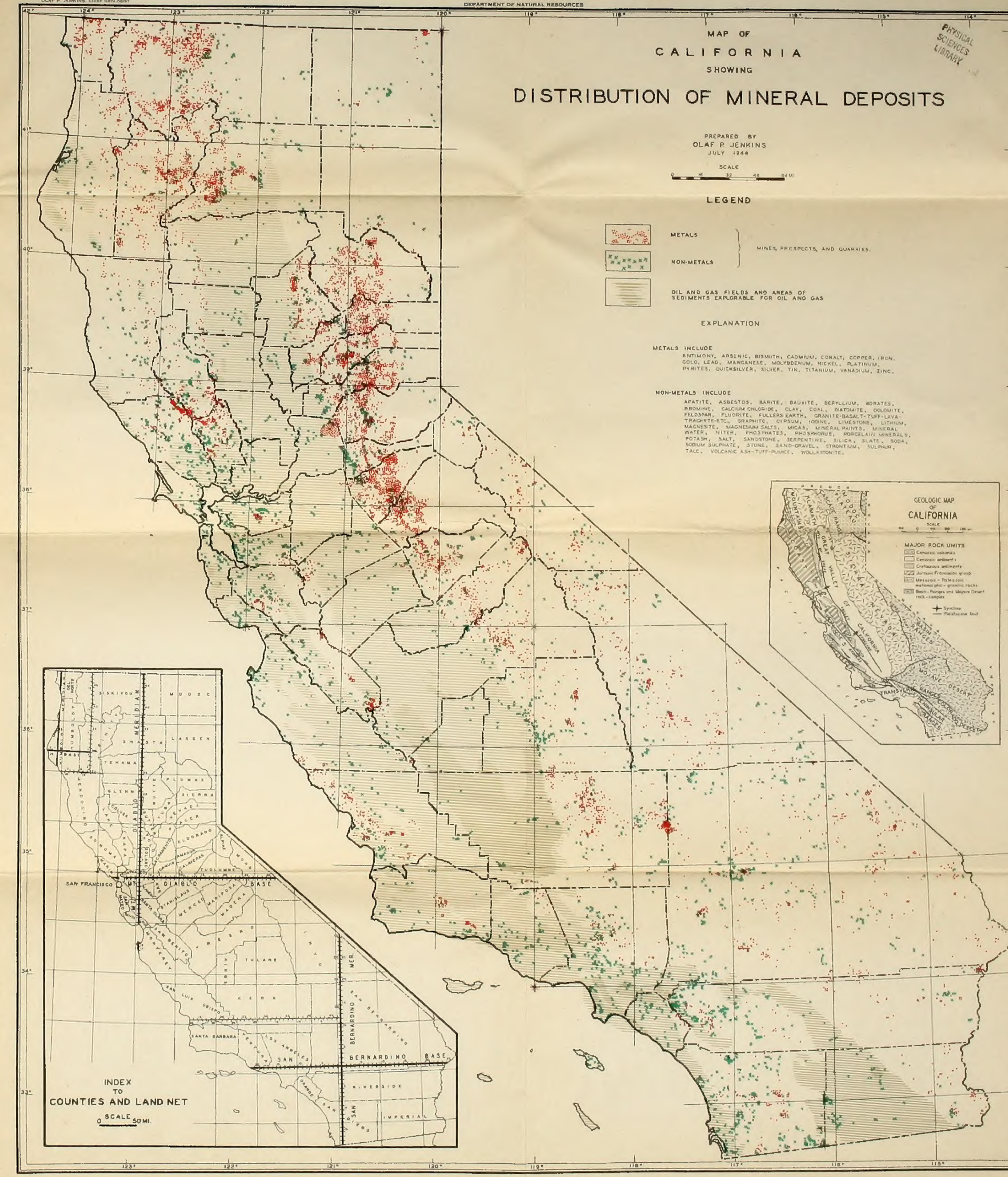


PLATE VIII. ACCOMPANYING STATE MINERALOGIST'S REPORT XL, APRIL, 1944